National Atmospheric Emissions Inventory

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Air Quality Pollutant Inventories for England, Scotland, Wales and Northern Ireland: 1990 – 2011

A report of the National Atmospheric Emissions Inventory

September, 2013

Aether RICARDO-AEA

Air Quality Pollutant Inventories for England, Scotland, Wales and Northern Ireland: 1990 – 2011

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Executive Summary

This is the Air Quality Pollutant Inventory Report for England, Scotland, Wales and Northern Ireland. The report presents emission inventories for the Devolved Administrations of the UK for the period 1990 to 2011, for the following priority Air Quality (AQ) pollutants:

- Ammonia (NH_3)
- Carbon monoxide (CO)
- Nitrogen oxides (NO_X as NO_2)
- Non-methane volatile organic compounds (NMVOCs)
- Sub-10 micron particulate matter (PM_{10})
- Sulphur dioxide (SO_2)
- Lead (Pb)

These inventories are compiled on behalf of the UK Department for Environment, Food & Rural Affairs, the Scottish Government, the Welsh Government and the Department of Environment for Northern Ireland, by the UK emission inventory teams at Ricardo-AEA, Aether and Rothamsted Research.

Data Sources and Inventory Methodology

The Devolved Administrations' inventories are compiled by disaggregating the UK emission totals presented within "UK Informative Inventory Report 1980 to 2011" (N R Passant *et al.*, 2013), derived from the National Atmospheric Emissions Inventory (NAEI) database. The emission estimates for each pollutant are presented in Nomenclature for Report (NFR) format, to be consistent with the UK inventory submissions to the United Nations Economic Commission for Europe (UNECE), which follow international inventory reporting guidelines.

The method for disaggregating UK emission totals across the Devolved Administrations (DAs) draws on a combination of point source data (e.g. Pollution Inventory[1] data for industrial emissions) and sub-national and local datasets such as:

- DECC sub-national statistics on energy use
- Other regional energy use data for specific industries or regional data on raw material consumption or sector-specific production
- Major road traffic count data
- Domestic and international flight data for all major UK airports
- Regional housing, employment, population and consumption data
- Agricultural surveys (livestock numbers, crop production, fertiliser application)
- Land use survey data

Emissions from the offshore oil and gas exploration and production sector are not attributed to a specific country inventory, but are reported within an "unallocated" category. Note, however, that emissions from onshore oil and gas terminals are assigned to the appropriate country inventories.

For many sources of AQ pollutants, the data available for Devolved Administration emissions are less detailed than for the UK as a whole, and for some sources, country-level data are not available at all. In particular, detailed energy balances to provide annual fuel-specific consumption data by source sector are not available for England, Scotland, Wales and Northern Ireland.

Sub-national energy statistics are published annually by the Department for Energy and Climate Change (DECC) within the quarterly Energy Trends[2] publication. These statistics are limited in their detail when

[1] The term "Pollution Inventory" is used here to represent the industrial emissions databases of the UK environmental regulators (The Environment Agency of England & Wales, the Scottish Environment Protection Agency and the Northern Ireland Department of Environment), which comprise annual emission estimates from all EPR/IPPC-regulated processes under their authority.

[2] The latest available data are taken from the December 2010 Energy Trends, http://www.decc.gov.uk/en/content/cms/statistics/publications/trends/trends.aspx

compared to UK-level energy statistics, but do provide estimated fuel use data for England, Scotland, Wales and Northern Ireland for the following source sectors:

- Industry
- Commercial
- Agriculture (combustion sources)
- Domestic

The DECC sub-national energy statistics have been developed in recent years to provide estimates of fuel use and CO_2 emissions data at Local Authority (LA) level across the UK. The latest available data include LA solid and liquid fuel use estimates for 2005 to 2010, with gas and electricity data also being available up to 2011.

The DECC data at local and regional level are derived from analysis of gas and electricity meter point data, supplemented by additional research to estimate the distribution of solid fuels and petroleum-based fuels across the UK. Since the initial study and presentation of experimental data for 2003 and 2004, each annual revision to the local and regional data has included data improvements through targeted sector research. These DECC sub-national energy statistics continue to evolve and improve, reducing data inaccuracies and are the best data available to inform the patterns of fuel use across the Devolved Administrations (DAs). They are therefore used to underpin the pollutant emission estimates from fuel combustion sources within the inventories presented here, in conjunction with other data sources such as EU Emissions Trading System (EU ETS) fuel use data for large industrial sites and other DA-specific energy data.

For other significant emission sources there are complete country-level datasets available, although some of these are less detailed than data used for the UK Inventory:

- Industrial process emissions are based on plant operator estimates reported to environmental agencies under regulatory systems such as Integrated Pollution Prevention and Control (IPPC). Major sources include power stations, cement and lime kilns, iron & steel works, aluminium and other non-ferrous metal plant, chemical industries. These data are not available across the full time-series from 1990, as the regulatory reporting regimes developed in the late 1990s (in England, Wales and Northern Ireland) and early 2000s (in Scotland);
- Emissions from oil and gas terminals and offshore platforms and rigs, are based on operator estimates reported to the DECC Offshore Inspectorate team in Aberdeen through the Environmental Emissions Monitoring System, EEMS;
- Agricultural emissions are based on UK emission factors and annual survey data across each of the Devolved Administrations, including estimates of arable production and livestock numbers;
- Emissions from waste disposal activities are estimated based on modelled emissions from the UK air quality inventory (Defra, 2012b) split out across the DAs based on local authority waste disposal activity reporting (www.wastedataflow.org) which provides an insight into the local shares of UK activity for recycling, landfilling, incineration and other treatment and disposal options. Waste incineration emissions are based on point source emissions data.

For some sources where regional data are not available, current local mapping grids have been used; these mapping grids are commonly based on census and other survey data that are periodically updated and used within UK emissions mapping and modelling work. For many sources, there is insufficient local data available back to 1990, and assumptions and extrapolations of available datasets have been used to present a time-series of air quality pollution emissions.

The inventories for England, Scotland, Wales and Northern Ireland aim to use the best available data. For most sources, more data are available in recent years than for 1990. For example, installation-specific fuel use data from major industrial plant under EU ETS are available from 2005 onwards and data for sites regulated under EPR/IPPC are available from 1998 onwards for England and Wales, 1999 onwards for Northern Ireland, and in 2002 and from 2004 onwards for Scotland. These data sources are used where possible to inform back-casting of emission estimates. As such there remains a greater level of uncertainty in emission estimates from the earlier part of the time-series compared to more recent years. Furthermore, the data quality from these environmental regulatory systems has evolved over the years, as monitoring, reporting and quality checking methods and protocols have developed. This also impacts upon the accuracy of the reported emissions of AQ

pollutants which are used within inventory compilation, such that more recent data are likely to be more accurate.

Air Quality Emission Inventories: Key Findings

The main findings of this report are summarised below:

ENGLAND

- Emissions of **ammonia** are estimated at 197kt in 2011. These emissions have declined by 19% since 1990 and account for 68% of the UK total in 2011. Agricultural sources dominate the inventory with manure management representing 61% of total ammonia emissions in 2011 and 33% coming from cattle manure management alone. Ammonia emissions in England have increased in recent years, with a 3% increase between 2008 and 2011 driven by higher emissions from fertiliser application and increasing emissions from composting and biogas production via anaerobic digestion.
- Emissions of **carbon monoxide** are estimated at 1,625kt in 2011 and have declined by 77% since 1990. England's emissions account for 76% of the UK total. In 2010, 38% of emissions stem from road transport combustion sources.
- Emissions of **nitrogen oxides** are estimated at 778kt in 2011, representing 75% of the UK total in 2011. Emissions have declined by 66% since 1990, with 36% stemming from road transport combustion sources and 23% from power generation.
- Emissions of **non-methane volatile organic compounds** are estimated at 529kt in 2011, representing a 73% reduction in emissions since 1990. This reduction has been dominated by the 95% decrease since 1990 in road transport sources, including evaporative losses. England represents 70% of the UK total.
- Emissions of **PM_{10}** are estimated at 85kt in 2011 and have declined by 59% since 1990. They account for 75% of the UK total. 23% of emissions come from road transport sources. Power generation accounted for 28% in 1990 but have been significantly reduced to 6% of England's total in 2011.
- Emissions of **sulphur dioxide** are estimated at 270kt in 2011, representing 71% of the UK total in 2011. Emissions have declined by 91% since 1990, which has been dominated by the 95% reduction in power generation due to the growth in gas and nuclear fuel use and the installation of FGD plant at a number of coal-fired power stations.
- Emissions of **lead** are estimated at 41t in 2011. Emissions have declined by 98% since 1990 and accounted for 71% of the UK total in 2011. The decline is dominated by the 1,799t reduction in transport sources due to the phase-out of leaded petrol. 30% of 2011 emissions arise due to the production in iron and steel industries.
- Source emission contributions to the 2011 inventory totals across all reported air quality pollutants are summarised in the table below:

Table ES1: England Air Quality Pollutant Inventories 2011: Source Emission Contributions

	CO	NH_3	NO_X	Pb	PM_{10}	SO_2	NMVOC
Energy Industries	3.9%	0.0%	25.8%	6.2%	6.9%	60.4%	0.0%
Industrial Combustion	25.2%	0.0%	17.3%	23.2%	10.2%	19.0%	3.4%
Transport Sources	42.0%	3.8%	45.5%	3.9%	26.4%	3.0%	8.9%
Commercial Combustion	6.5%	0.0%	3.4%	0.8%	9.0%	0.5%	2.1%
Public Sector Combustion	0.1%	0.0%	1.0%	1.5%	0.5%	1.0%	0.0%
Residential Combustion	11.9%	0.6%	3.3%	6.0%	12.9%	6.0%	2.5%
Fugitive emissions (Energy)	0.2%	0.0%	0.0%	4.2%	0.4%	2.4%	13.9%
Industrial Processes	8.3%	2.3%	0.6%	51.5%	14.7%	5.7%	7.8%
Solvent Processes	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	55.5%
Agriculture	0.0%	84.4%	0.0%	0.0%	9.1%	0.0%	0.0%
Waste	0.0%	7.5%	0.0%	0.0%	0.0%	0.0%	0.0%
Other	1.8%	1.4%	3.0%	2.8%	9.8%	2.0%	5.9%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

SCOTLAND

- Emissions of **ammonia** are estimated at 36kt in 2011. These emissions have declined by 23% since 1990 and account for 13% of the UK total in 2011. Manure management represents 65% of total ammonia emissions in 2011, which has declined by 11% since 1990. Ammonia emissions in Scotland have increased in recent years, with a 7% increase between 2008 and 2011 driven primarily by increasing emissions from composting and biogas production via anaerobic digestion.
- Emissions of **carbon monoxide** are estimated at 187kt in 2011 and have declined by 79% since 1990. Scotland's emissions account for 9% of the UK total. Road transport combustion sources accounted for 28% of emissions in 2011. The sharp (16%) decrease in carbon monoxide emissions between 2008 and 2009 was predominantly driven by this sector.
- Emissions of **nitrogen oxides** are estimated at 98kt in 2011, representing 10% of the UK total in 2011. Emissions have declined by 65% since 1990, with 29% of total emissions in 2011 stemming from road transport combustion sources and a further 25% from power generation.
- Emissions of **non-methane volatile organic compounds** are estimated at 122kt in 2011, representing a 70% reduction in emissions since 1990. The food and drink sector represents 45% of emissions dominated by brewers and distilleries. Fugitive emissions from fuels make up 14% of the 2011 total and have reduced by 90% since 1990. Road transport emissions have been reduced by 96% since 1990.
- Emissions of **PM_{10}** are estimated at 12kt in 2011 and have declined by 58% since 1990. They accounted for 11% of the UK total in 2011. 38% of emissions come from commercial, domestic and agricultural combustion, and emissions from power generation accounted for 25% in 1990 but have been reduced to 8% of Scotland's total in 2011.
- Emissions of **sulphur dioxide** are estimated at 61kt in 2011, representing 16% of the UK total in 2011. Emissions have declined by 79% since 1990, which has been dominated by the 79% reduction in power generation due to the growth in gas, renewable and nuclear fuel use. Recent fluctuating trends in electricity generation have had a noticeable impact on emissions.
- Emissions of **lead** are estimated at 3.1t in 2011. Emissions have declined by 99% since 1990 and accounted for 5% of the UK total in 2011. The decline is dominated by the >99% reduction in transport sources due to the phase-out of leaded petrol. 30% of 2011 emissions arise from industrial combustion.
- Source emission contributions to the 2011 inventory totals across all reported air quality pollutants are summarised in the table below:

Table ES2: Scotland Air Quality Pollutant Inventories 2011: Source Emission Contributions

	CO	NH_3	NO_X	Pb	PM_{10}	SO_2	NMVOC
Energy Industries	6.6%	0.0%	31.6%	20.6%	8.8%	78.2%	0.0%
Industrial Combustion	20.4%	0.0%	15.7%	29.9%	7.1%	4.5%	1.6%
Transport Sources	31.6%	2.1%	38.4%	5.7%	19.6%	2.5%	3.2%
Commercial Combustion	8.0%	0.0%	6.5%	2.7%	12.4%	0.3%	1.6%
Public Sector Combustion	0.1%	0.0%	1.0%	2.1%	0.4%	0.7%	0.0%
Residential Combustion	28.5%	0.9%	3.7%	23.9%	24.8%	11.5%	2.8%
Fugitive emissions (Energy)	0.5%	0.0%	0.0%	0.0%	2.6%	0.2%	14.1%
Industrial Processes	2.5%	0.2%	0.0%	11.3%	9.6%	1.3%	49.2%
Solvent Processes	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	23.4%
Agriculture	0.0%	85.9%	0.0%	0.0%	8.7%	0.0%	0.0%
Waste	0.0%	10.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Other	1.7%	0.7%	3.0%	3.8%	6.0%	0.9%	4.2%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

WALES

- Emissions of **ammonia** are estimated at 27kt in 2011. These emissions have declined by 14% since 1990 and account for 9% of the UK total in 2011. Manure management represented 65% of total ammonia emissions in 2011, with 49% of total emissions originating from cattle manure management alone. Ammonia emissions in Wales have increased in recent years, with a 6% increase between 2009 and 2011 driven primarily by increasing emissions from fertiliser application, dairy cattle manure management, composting and biogas production via anaerobic digestion.
- Emissions of **carbon monoxide** are estimated at 225kt in 2011 and have declined by 66% since 1990. Wales' emissions account for 11% of the UK total. The iron and steel industry contributed to 42% of the 2011 total, decreasing by 66% since 1990. The additional industrial output from Wales during 2006 and 2011 resulted in an increase in emissions for these years.
- Emissions of **nitrogen oxides** are estimated at 78kt in 2011, representing 8% of the UK total in 2011. Emissions have declined by 56% since 1990, with 30% of emissions in 2011 stemming from power generation. Recent trends in electricity generation have dominated the overall trends, with large fluctuations in coal-fired power generation.
- Emissions of **non-methane volatile organic compounds** are estimated at 42kt in 2011, representing a 69% reduction in emissions since 1990. This reduction has been dominated by the 95% decrease in road transport sources since 1990, as well as the 60% decline in the solvent and other product use sector. This sector accounted for 42% of emissions in 2011.
- Emissions of **PM_{10}** are estimated at 9kt in 2011 and have declined by 52% since 1990. They account for 8% of the UK total in 2011. 37% of emissions come from commercial, domestic and agricultural combustion and emissions from road transport sources accounted for 14%.
- Emissions of **sulphur dioxide** are estimated at 31kt in 2011, representing 8% of the UK total in 2011. Emissions have declined by 83% since 1990. Petroleum refineries are the most significant source in Wales, accounting for 43% of emissions. The installation of FGD at Aberthaw station has contributed to a reduction in emissions from power generation to only 11% in 2010, from 53% in 2006.
- Emissions of **lead** are estimated at 12.4t in 2011. Emissions have declined by 91% since 1990 and accounted for 21% of the UK total in 2011. The decline is dominated by the >99% reduction in transport sources due to the phase-out of leaded petrol. 78% of 2011 emissions came from industrial processes.
- Source emission contributions to the 2011 inventory totals across all reported air quality pollutants are summarised in the table below:

Table ES3: Wales Air Quality Pollutant Inventories 2011: Source Emission Contributions

	CO	NH_3	NO_X	Pb	PM_{10}	SO_2	NMVOC
Energy Industries	3.3%	0.0%	39.7%	3.1%	9.1%	55.3%	0.0%
Industrial Combustion	14.1%	0.0%	16.1%	7.6%	6.3%	13.2%	3.2%
Transport Sources	18.2%	1.7%	30.6%	0.9%	16.7%	3.8%	6.5%
Commercial Combustion	2.9%	0.0%	5.1%	0.5%	7.3%	0.4%	2.2%
Public Sector Combustion	0.1%	0.0%	0.6%	0.5%	0.4%	0.8%	0.0%
Residential Combustion	18.2%	1.2%	3.1%	4.6%	28.8%	9.7%	6.8%
Fugitive emissions (Energy)	2.6%	0.0%	0.0%	4.4%	0.6%	3.3%	29.0%
Industrial Processes	40.0%	0.2%	3.5%	77.9%	21.3%	12.9%	5.3%
Solvent Processes	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	41.6%
Agriculture	0.0%	90.2%	0.0%	0.0%	4.8%	0.0%	0.0%
Waste	0.0%	5.9%	0.0%	0.0%	0.0%	0.0%	0.0%
Other	0.6%	0.8%	1.3%	0.5%	4.7%	0.7%	5.2%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

NORTHERN IRELAND

- Emissions of **ammonia** are estimated at 30kt in 2011. These emissions have declined by 6% since 1990 and account for 10% of the UK total in 2011. Manure management represents 80% of total ammonia emissions in 2011, with 59% of total emissions originating from cattle manure management alone. Notably, ammonia emissions in Northern Ireland have increased in recent years, with a 2% increase between 2009 and 2011; this increase is driven by higher emissions from dairy cattle wastes and increasing emissions from composting and biogas production via anaerobic digestion.
- Emissions of **carbon monoxide** are estimated at 86kt in 2011 and have declined by 76% since 1990. Northern Ireland's emissions accounted for 4% of the UK total in 2011. Road transport combustion sources accounted for 25% of emissions in 2011, decreasing by 88% since 1990. Commercial, agricultural and domestic combustion represented 42% of total emissions, showing a comparable reduction to road transport of 78% since 1990.
- Emissions of **nitrogen oxides** are estimated at 32kt in 2011, representing only 3% of the UK total in 2011. Emissions have declined by 67% since 1990, with 35% of total emissions in 2011 stemming from road transport. Industrial combustion accounted for 17% of 2011 emissions and 18% came from power generation.
- Emissions of **non-methane volatile organic compounds** are estimated at 18kt in 2011, representing a 72% reduction in emissions since 1990. This reduction has been dominated by the 96% decrease since 1990 in road transport sources, including evaporative losses. The solvent and other product use sector made up 53% of emissions in 2011.
- Emissions of **PM_{10}** are estimated at 5kt in 2011 and have declined by 66% since 1990. They accounted for 5% of the UK total in 2011. 41% of emissions came from commercial, domestic and agricultural combustion, which has declined by 75% since 1990. Emissions from road transport sources accounted for 15% of emissions in 2011.
- Emissions of **sulphur dioxide** are estimated at 13kt in 2011, representing 4% of the UK total in 2011. Power generation has dominated the 88% decline in sulphur dioxide emissions since 1990. Due to the sulphur in coal and fuel oil, power generation accounted for 61% of emissions in 1990 but has since been reduced by 97%. Domestic combustion was the most significant source of emissions (49%) in 2011.
- Emissions of **lead** are estimated at 1.5t in 2011. Emissions have declined by 98% since 1990 and accounted for 2% of the UK total in 2011. The decline is dominated by the >99% reduction in transport sources due to the phase-out of leaded petrol. Domestic combustion accounted for 34% of emissions in 2011.
- Source emission contributions to the 2011 inventory totals across all reported air quality pollutants are summarised in the table below:

Table ES4: Northern Ireland Air Quality Pollutant Inventories 2011: Source Emission Contributions

	CO	NH_3	NO_X	Pb	PM_{10}	SO_2	NMVOC
Energy Industries	2.3%	0.0%	17.6%	1.7%	1.0%	17.2%	0.0%
Industrial Combustion	27.5%	0.0%	16.9%	45.0%	9.8%	26.3%	3.8%
Transport Sources	27.1%	1.2%	42.6%	4.5%	16.9%	3.5%	7.1%
Commercial Combustion	5.6%	0.0%	10.6%	3.5%	10.9%	1.0%	4.3%
Public Sector Combustion	0.1%	0.0%	0.9%	3.4%	0.6%	1.7%	0.0%
Residential Combustion	36.3%	0.4%	9.2%	34.2%	29.2%	49.3%	9.4%
Fugitive emissions (Energy)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.9%
Industrial Processes	0.0%	0.0%	0.0%	5.1%	6.3%	0.0%	11.7%
Solvent Processes	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	52.6%
Agriculture	0.0%	94.5%	0.0%	0.0%	20.5%	0.0%	0.0%
Waste	0.0%	3.7%	0.0%	0.0%	0.0%	0.0%	0.0%
Other	1.1%	0.3%	2.1%	2.7%	4.8%	1.1%	6.1%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Per capita emissions

Emissions per capita have been calculated for each of the DAs and are summarised for each pollutant within the report. Key features are described within the pollutant specific sections of the report, and a brief summary of the findings is described below:

- Across all DAs, for all pollutants, per capita emissions have fallen between 1990 and 2011.
- The most notable decrease (in percentage terms) is for lead, with a decrease of more than 90% across all of the DAs.
- In England, per capita emissions are lower than the UK average for all pollutants in 2011.
- In Northern Ireland, ammonia emissions per capita are over three times the UK average in 2011. This is due to the very high contribution of emissions from agriculture, relative to the rest of the UK; Northern Ireland accounted for 10% of UK ammonia emissions, compared with just 3% of the UK population.
- Sulphur dioxide emissions per capita in Scotland are higher than the UK average, due to the high contribution of Scottish emissions from domestic combustion and power stations to the UK totals for these sectors (21% and 34%, respectively, compared with only 8% of the UK population).
- Scottish NMVOC emissions per capita are nearly two times the UK average in 2011, mostly due to the high contribution of emissions from food and drink industry.
- Welsh emissions are much higher than the UK average for NO_x, PM_{10}, SO_2, and most notably for Pb and CO. This is predominantly due to the contribution of iron and steel industry emissions to the Welsh total.

Contacts

This work forms part of the Atmosphere & Local Environment (ALE) Programme of the Department for Environment, Food and Rural Affairs. Ricardo-AEA and Aether compile emission estimates for the energy, industrial process, solvents and waste sectors. The Centre for Ecology and Hydrology (Edinburgh) provides emission estimates for land use, land use change and forestry sources. Rothamsted Research provides the estimates of agricultural emissions.

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A copy of this report and related data may be found on the Defra NAEI website:

http://naei.defra.gov.uk/

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1.1 BACKGROUND TO INVENTORY DEVELOPMENT FOR THE DEVOLVED ADMINISTRATIONS

The development of Air Quality (AQ) pollutant emission inventories for each of the Devolved Administrations (DAs) has been commissioned by Defra in order to better inform energy and environmental policy-makers within the Devolved Administrations in their pursuit of objectives set by the Air Quality Strategy for England, Scotland, Wales and Northern Ireland (AQS for ESWNI). These objectives also contribute to the UK's targets as a whole in terms of meeting both national and international targets on both local and transboundary air pollution.

The provision of DA-level datasets and subsequent identification of key sources at more regional and local levels is a key step to enable prioritisation of local action and to highlight the potential impacts of specific policies and measures. The time-series of AQ pollutant emissions provides an insight into the effects of environmental policies introduced since 1990, and may help to identify where win-win policies could be pursued to achieve both Air Quality and Greenhouse Gas policy goals.

1.1.1 Air quality emission reduction drivers

Overall air quality in the UK is currently estimated to be better than at any time since the industrial revolution. However air pollution is still estimated to reduce the life expectancy of every person in the UK. COMEAP (2010) estimated the burden in the UK of anthropogenic particulate matter air pollution in 2008 as a loss of life expectancy from birth of approximately six months. The burden was also calculated as an effect on mortality in 2008 equivalent to nearly 29,000 deaths in the UK at typical ages and an associated loss of total population life of 340,000 life-years. A number of policies are currently in place in the UK, which aims to improve air quality. This includes the National Air Quality Strategy for England, Scotland, Wales and Northern Ireland.

Air Quality Strategy for England, Scotland, Wales and Northern Ireland
The original National Air Quality Strategy (NAQS) published in 1997 (DOE 1997) set out a framework of standards and objectives for the air pollutants of most concern (SO_2, PM_{10}, NO_X, CO, lead, benzene, 1, 3-butadiene and tropospheric ozone). The aim of the strategy was to reduce the air pollutant impact on human health by reducing airborne concentrations.

The NAQS identified air quality standards for eight priority pollutants based on the recommendations of the Expert Panel on Air Quality Standards (EPAQS, 1995) or World Health Organisation (WHO) guidance where no EPAQS recommendation existed. The NAQS has been subject to periodic review, with consultation documents being published in 1998 and 2001 (DETR 1998a, Defra 2001), and has subsequently evolved into the Air Quality Strategy for England, Scotland, Wales and Northern Ireland (AQS for ESWNI), with the same goals. A second edition of the strategy was published in 2000 (DETR 2000), identifying further revisions and focused on the incorporation of air quality limit values in European Directives, and the impacts of devolution. On 17 July 2007 a new Air Quality Strategy was published by Defra and the Devolved Administrations. The details of this AQS can be found on the Defra website[3].

The new Air Quality Strategy supersedes previous versions and covers the whole of the UK, therefore including DA-specific objective values that were previously detailed in addenda to the previous AQS.

[3] https://www.gov.uk/government/publications/the-air-quality-strategy-for-england-scotland-wales-and-northern-ireland-volume-2

EU Air Quality Framework Directive

The EU air quality framework directive (96/62/EC) established a framework for setting limit values, assessing concentrations and managing air quality to avoid exceeding the limits for air pollutants known to be harmful to human health and the environment through a series of four Daughter Directives. However, in 2008, the Framework Directive and first three Daughter Directives were consolidated in a new EU Air Quality Directive (2008/50/EC). The 4th Daughter Directive (2004/107/EC) is expected to be merged with the Air Quality Directive in the future.

At present, under 2008/50/EC and the 4th Daughter Directive, limit values are set for twelve pollutants, including NO_X, SO_2, PM and CO, and member states are required to submit annual reports to the European Commission on whether the limits have been achieved within their respective areas.

UNECE Convention on Long-Range Transboundary Air Pollution

The UK is committed to reducing acidifying gas and ozone precursor emissions and is a Party to several protocols under the UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP).

Under the Second Sulphur Protocol, the UK committed to reducing its total sulphur dioxide emissions by 50% by 2000, 70% by 2005 and 80% by 2010 (all from a 1980 baseline).

The NMVOC Protocol requires the UK to achieve a 30% reduction of anthropogenic NMVOC emissions by 1999 from a 1988 baseline. The emission estimates given in the 1999 version of the emissions inventory indicated that this was achieved.

The NO_X Protocol required that the total emissions of NO_X in 1994 should be no higher than they were in 1987; UK emissions were 11% lower in 1994 than in 1987 and have fallen substantially since 1994.

In 1996, the UNECE started negotiating a new multi-effect, multi-pollutant protocol on nitrogen oxides and related substances. This was aimed at addressing photochemical pollution, acidification and eutrophication. The Protocol to Abate Acidification, Eutrophication and Ground-level Ozone was adopted in Gothenburg in December 2000, where it was signed by the UK. It incorporates several measures to facilitate the reduction of emissions:

- Emission ceilings are specified for sulphur, nitrogen oxides, ammonia and NMVOCs;
- Emission limits are specified for sulphur, nitrogen oxides and NMVOCs from stationary sources;
- Emission limits are indicated for carbon monoxide, hydrocarbons, nitrogen oxides and particulates from new mobile sources;
- Environmental specifications for petrol and diesel fuels are given;
- Several measures to reduce ammonia emissions from the agriculture sector are required.

The Gothenburg Protocol was amended in 2012 to include national emission reduction commitments (expressed as percentage reduction from 2005 levels) to be achieved in 2020 and beyond. Several of the Protocol's technical annexes were also revised with updated sets of emission limit values for both key stationary sources and mobile sources, as well as the addition of emission reduction commitment for $PM_{2.5}$. More detailed information on both of the Gothenburg protocol and the Convention may be found at the UNECE web site: www.unece.org/env/lrtap/

National Emissions Ceilings Directive

Within the EU, the National Emission Ceilings Directive was agreed in 2001. It sets emission ceilings to be achieved from 2010 onwards for each Member State for the same four pollutants as in the Gothenburg Protocol. The UK has met current international targets to reduce total emissions by 2010 of four air pollutants that cause harm to people's health and to the natural environment:

- Emissions of **sulphur dioxide** have fallen by 90 per cent between 1990 and 2011, and decreased by 7 per cent between 2010 and 2011. Emissions in 2011 were 35 per cent below the lowest international target for the UK.

- Emissions of **nitrogen oxides** have fallen by 64 per cent between 1990 and 2011, and fell by 7 per cent between 2010 and 2011. Emissions in 2011 were 11 per cent below the lowest international target for the UK.
- Emissions of **non-methane volatile organic compounds** have fallen by 72 per cent between 1990 and 2011, and fell by 3 per cent between 2010 and 2011. Emissions in 2011 were 37 per cent below the international target for the UK.
- Emissions of **ammonia** have fallen by 18 per cent between 1990 and 2011, but increased by 2 per cent between 2010 and 2011. Emissions in 2011 were 2 per cent below the international target for the UK.

More information on these ceilings can be found in a statistical release from Defra (2012a).

Large Combustion Plant Directive
Within the UK, the implementation of the EC's Large Combustion Plant Directive and other associated policy measures has led to substantial reductions in acidifying pollutants, specifically NO_X, SO_2 and dust from power plants and industrial sources.

Sulphur Content of Liquid Fuels Directive
The EC's Directive to limit sulphur content in gas oil and fuel oil has been transposed into UK regulations which were initially established in 2000 but were updated with Statutory Instruments brought into force across the DAs via the Sulphur Content of Liquid Fuel Regulations 2007 (England and Wales: SI79/2007; Scotland: SI 27/2007; Northern Ireland: SI 272/2007). The main impact of these regulations has been to gradually drive down the maximum sulphur content of refinery products, with the 2007 Regulations requiring that gas oil has a maximum 0.1% content Sulphur by mass from January 2008 onwards. The impacts of this change are evident within the recent emission trends of the UK and DA inventories as SO_2 emissions have declined significantly between 2007 and 2008 from road transport (1A3b) and other sources where petroleum-based fuels are dominant.

UNECE Heavy Metals Protocol
The Convention on Long-range Transboundary Air Pollution was signed in 1979 and came into force in 1983. Since its entry into force, the Convention has been extended by a number of protocols, including the 1998 Protocol on Heavy Metals. This Protocol is given in outline below; more information may be found at the UN/ECE web site, located at: http://www.unece.org/env/lrtap/. The UK has signed this protocol.

The UNECE Protocol on Heavy Metals targets three particularly harmful substances: lead, cadmium and mercury. Countries are obliged to reduce their emissions of these three metals below their levels in 1990 (or an alternative year between 1985 and 1995). The protocol aims to cut emissions from industrial sources (iron and steel industry, non-ferrous metal industry), combustion processes (power generation, road transport) and waste incineration.

The protocol specifies limit values for emissions from stationary sources and requires the use of Best Available Technology (BAT) to minimise emissions from these sources, through the application of special filters or scrubbers for combustion sources, or mercury-free processes. The protocol also required countries to phase out leaded petrol. Under the protocol, measures are introduced to lower heavy metal emissions from other products (such as mercury in batteries) and examples are given of management measures for other mercury containing products, such as electrical components (thermostats, switches), measuring devices (thermometers, manometers, barometers), fluorescent lamps, dental amalgam, pesticides and paint.

The protocol was amended in 2012 to introduce more stringent emission limit values for emissions of particulate matter and of the specific heavy metals cadmium, lead and mercury applicable for certain combustion and other industrial emission sources releasing them into the atmosphere. The emission source categories for the three heavy metals were also extended to the production of silico- and ferromanganese alloys.

1.2 INVENTORY METHOLODOGY AND DATA AVAILABILITY

This report presents emission inventories for the Devolved Administrations of the UK for the period 1990 to 2011, for the following priority Air Quality (AQ) pollutants:

- Ammonia (NH_3)
- Carbon monoxide (CO)
- Nitrogen oxides (reported as nitrogen dioxide) (NO_X as NO_2)
- Non-methane volatile organic compounds (NMVOC)
- Sub-10 micron particulate matter (PM_{10})
- Sulphur dioxide (SO_2)
- Lead (Pb)

The estimates have been compiled by disaggregating the UK emission totals presented within "UK Informative Inventory Report 1980 to 2011" (Passant *et al.*, 2013), derived from the National Atmospheric Emissions Inventory (NAEI) database. The UK data is compiled annually in accordance with the requirements of United Nations Economic Commission for Europe (UNECE) reporting guidelines using the Nomenclature for Report (NFR) format and submitted to the Convention on Long-Range Transboundary Air Pollution (CLRTAP).

1.2.1 Background: Data Availability and Inventory Uncertainty

The method for disaggregating UK emission totals across the Devolved Administrations draws on a combination of point source data (e.g. Pollution Inventory[4] data for industrial emissions) and sub-national and local datasets such as:

- DECC sub-national statistics on energy use;
- Other regional energy use data for specific industries or regional data on raw material consumption or sector-specific production;
- Major road traffic count data;
- Domestic and international flight data for all major UK airports;
- Rail company fuel use estimates;
- Regional housing, employment, population and consumption data;
- Agricultural surveys (livestock numbers, crop production, fertiliser application);
- Land use survey data.

Emissions from the offshore oil & gas exploration and production sector are not attributed to a specific country inventory, but are reported within an "unallocated" category. Note, however, that emissions from onshore oil & gas terminals are assigned to the appropriate country inventories.

The disaggregation of air quality (AQ) pollutant emissions across the four Devolved Administrations of the UK has been conducted five times previously and this report presents the results from a programme of on-going data and methodology improvement, to provide emission inventories for the Devolved Administrations (DAs). This programme spans both GHG and AQ emission inventories, and is driven by the developing requirements for sub-national reporting against emission targets and DA policy development.

For many emission sources of AQ pollutants, the data available for Devolved Administration emissions are less detailed than for the UK as a whole, and for some sources country-level data are not available at all. For this reason, a "top-down" approach using UK inventory data as the core dataset has been adopted, and percentage splits of the UK total have been derived for each of the constituent countries using available regional data.

In particular, energy balance data (i.e. fuel production, transformation and sector-specific consumption data) are not available for England, Wales and Scotland. Sub-national energy statistics are published annually by the

[4] The term "Pollution Inventory" is used here to represent the industrial emissions databases of the UK environmental regulators (The Environment Agency of England & Wales, the Scottish Environment Protection Agency and the Northern Ireland Department of Environment) which comprise annual emission estimates from all EPR/IPPC-regulated processes under their authority.

Department for Energy and Climate Change (DECC) within the quarterly Energy Trends[5] publication. These sub-national statistics are limited in their detail when compared to UK-level energy statistics, but do provide estimated fuel use data for England, Scotland, Wales and Northern Ireland for the following source sectors:

- Industry
- Commercial
- Agriculture (combustion source)
- Domestic

The DECC sub-national energy statistics have been developed in recent years to provide estimates of fuel use and CO_2 emissions data at Local Authority (LA) level across the UK. The latest available data include LA solid and liquid fuel use estimates for 2005 to 2010, with gas and electricity data also being available up to 2011.

The DECC data at local and regional level are derived from analysis of gas and electricity meter point data, supplemented by additional research to estimate the distribution of solid fuels and petroleum-based fuels across the UK. Since the initial study and presentation of experimental data for 2003 and 2004, each annual revision to the local and regional data has included data improvements through targeted sector research. These DECC sub-national energy statistics continue to evolve and improve, reducing data inaccuracies, and are the best data available to inform the patterns of fuel use across the Devolved Administrations. They are therefore used to underpin the pollutant emission estimates from fuel combustion sources within the inventories presented here, in conjunction with other data sources such as EU ETS fuel use data for large industrial sites and other DA-specific energy data.

For other significant emission sources there are complete country-level datasets available, although some of these are less detailed than data used for the UK Inventory:

- Industrial process emissions are based on plant operator estimates reported to environmental agencies under regulatory systems such as Integrated Pollution Prevention and Control (IPPC). Major sources include power stations, cement and lime kilns, iron & steel works, aluminium and other non-ferrous metal plant, chemical industries. These data are not available across the full time series from 1990, as the regulatory reporting regimes developed in the late 1990s (in England, Wales and Northern Ireland) and early 2000s (in Scotland);

- Emissions from oil and gas terminals and offshore platforms and rigs, are based on operator estimates reported to the DECC Offshore Inspectorate team (2012) in Aberdeen through the Environmental Emissions Monitoring System, EEMS;

- Agricultural emissions are based on UK emission factors and annual survey data across each of the Devolved Administrations, including estimates of arable production and livestock numbers (Rothamsted Research, 2012);

- Emissions from waste disposal activities are estimated based on modelled emissions from the UK air quality inventory (Defra, 2012b) split out across the DAs based on local authority waste disposal activity reporting (www.wastedataflow.org) which provides an insight into the local shares of UK activity for recycling, landfilling, incineration and other treatment and disposal options. Waste incineration emissions are based on point source emissions data.

- For some sources where regional data are not available, current local mapping grids have been used; these mapping grids are commonly based on census and other survey data that are periodically updated and used within UK emissions mapping and modelling work (Tsagatakis *et al.*, 2013).

In many source sectors, there is insufficient local data available back to 1990 or earlier, and assumptions and extrapolations of available datasets have frequently been used to present a time-series of air quality pollution emissions.

[5] The latest available data are taken from the December 2011 Energy Trends, http://www.decc.gov.uk/en/content/cms/statistics/publications/trends/trends.aspx

As a result of the more limited DA-specific activity and emission factor data, the emission estimates for the England, Scotland, Wales and Northern Ireland inventories are subject to greater uncertainty than the equivalent UK estimates. There are step-changes in data availability during the time-series, such as installation-specific fuel use data from major industrial plant under EU ETS (from 2005 onwards) and sites regulated under Environmental Permitting Regulations / Integrated Pollution Prevention and Control (EPR/IPPC) (1998 onwards for England and Wales, 1999 onwards for Northern Ireland, and in 2002 and from 2004 onwards for Scotland). These data sources are used where possible to inform back-casting of emission estimates, but there remains a greater level of uncertainty in emission estimates from the earlier part of the time-series compared to more recent years. Furthermore, the data quality from these environmental regulatory systems has evolved over the years, as monitoring, reporting and quality checking methods and protocols have developed. This also impacts upon the accuracy of the reported emissions of AQ pollutants which are used within inventory compilation, such that more recent data are likely to be more accurate. The uncertainties in the DA air quality inventories are discussed in more detail in Chapter 3.

1.2.2 Inventory Compilation Method

A comprehensive list of all sources and UK emissions for the target pollutants (CO, NO_X, SO_2, VOC, NH_3, PM_{10}, and Pb) during the study period of 1990-2011 is available from the NAEI database. From these data, the key sources for each of the AQ pollutants can be determined. The DA share of the UK emissions from each source category are then determined using the best available regional data, which may range from good quality emissions or activity data, to the use of proxy data (e.g. production or employment indices, population data) to provide a "best estimate" of the DA share of the UK emissions from a given source.
There are a number of resources that have been used to analyse the DA share of UK emissions for each emission source, including:

- NAEI point source database;
- Emissions mapping grid data;
- Regional data derived from analysis of activity data trends, taken from research to develop DA Greenhouse Gas (GHG) Inventories;
- Generic parameters and proxy data such as population or regional GDP data.

The development of more consistent reports and datasets between different scales (national-regional-local) derived from the NAEI database is a key improvement that this study has enabled. The main resources used within the DA air quality pollutant inventory analysis are outlined below.

1.2.2.1 NAEI Point Source Database

Operators of all EPR/IPPC-regulated industrial plant are required to submit annual emission estimates of a range of pollutants (including all of those pertinent to this study) to their local UK environmental regulatory agency, and these emission estimates are subject to established procedures of Quality Assurance and Quality Checking prior to publication. These industrial point-source pollution inventories (held by the Environment Agency, the Scottish Environment Protection Agency and the Northern Ireland Environment Agency) are emission datasets that have been developing and improving since their inception in the mid-1990s. Robust and reliable data for installations in England and Wales have been widely available since around 1998, whilst the equivalent datasets in Scotland and Northern Ireland became available from the early 2000s.

NAEI point source data have been improved over recent years through the increasing quality and availability of these EPR/IPPC-regulated industrial pollution emission datasets, as well as through the availability of site-specific fuel use data for sites that operate within the EU Emissions Trading System (EU ETS), which has been running since 2005. Annual data requests are also made directly to plant operators in key sectors such as power stations, refineries, cement & lime manufacture, iron & steel manufacture, chemical industry and waste treatment and disposal, in order to procure more detailed emissions data and other parameters (e.g. production data).

As part of the Devolved Administrations Inventory Improvement Programme, a research study was undertaken in early 2010 to source more detailed information on emissions sources at a number of petrochemical and

industrial sites across the UK. The study included consultation with Environment Agencies responsible for each of the respective Devolved Administrations and site visits to review further details of applications and reports submitted in relation to permitted activities.

Through analysis of the time-series of data and review of the latest emission estimates, the point source data is amended as appropriate to fill in gaps and rectify any errors. These finalised data are then used as the basis for the NAEI industrial emissions estimates. The location of each site is known and therefore the point-source database can be queried to extract all emissions information relevant to a given geographical area, and hence the DA-level inventories can partly be populated in this way.

Although the use of this dataset can only provide a limited time-series of emissions from a given source sector, it is nevertheless a useful tool for deriving recent regional emissions data for a broad range of pollutants, including CO, NO_X, SO_2, VOC, Pb, NH_3 and PM_{10}. The NAEI point-source database is most useful for industries that are dominated by large EPR/IPPC-authorised plant, such as power stations, refineries, iron & steel manufacturing, cement and lime kilns and so on. For these sectors, the point source database covers nearly 100% of emissions, and is regarded to be the best available dataset for such sources, as it is largely based on energy use and emissions data derived from regulatory agency sources that are subject to quality checking and (in the case of EU ETS data) independent verification.

Annual revisions to the NAEI point source database are conducted when new data become available and/or when installation-level data are revised by operators, regulators or through enquiry by the UK inventory team to resolve data discrepancies which may be evident between reporting mechanisms.

1.2.2.2 NAEI Emission Mapping Grids

Emission maps for the whole of the UK are routinely produced as part of the NAEI for 25 pollutants, including all of the pollutants considered in this study. The maps are compiled at a 1km resolution and are produced annually for the most recent NAEI database (2011 in this case). The mapped emissions data are available on the NAEI web site at: http://naei.defra.gov.uk/data/mapping

The emission maps are used by the UK inventory team and other organisations for a variety of Government policy support work at the national scale. In particular, the maps are used as input into a programme of air pollution modelling studies.

The geographical distribution of emissions across the UK is built up from distributions of emissions in each source sector. These source sector distributions are developed using a set of statistics appropriate to that sector. For large industrial 'point' sources, emissions are compiled from a variety of official UK sources (Environment Agency, Scottish Environment Protection Agency, Northern Ireland Environment Agency Local Authority data). For sources that are distributed widely across the UK (known as 'area' sources), a distribution map is generated using appropriate surrogate statistics for that sector. The method used for each source varies according to the data available, but is commonly based on either local activity statistics such as raw material use, energy use, industrial production and employment data, housing and population data, road vehicle and fuel sales data, periodic census or socio-economic survey data.

Periodic surveys and censuses of industrial, commercial, domestic, and other economic sectors provide indicators regarding the location and scale of a wide variety of activity data that can be used to disaggregate emissions totals, and these are commonly utilised within the NAEI mapping grids. For a more detailed description of the integration of point source data analysis and the development of UK emission maps, see the latest NAEI mapping methodology report available at the website given above (Tsagatakis et al., 2013). Appendix B of this report provides a summary table of the mapping grid data availability for each UNECE sector. Changes to the mapping grids used in the 1990-2011 inventory include use of the latest release of the Land Cover Maps from CEH to update the forestry and land use change mapping grids (http://www.ceh.ac.uk/landcovermap2007.html).

The key limitation to the use of mapping grids within inventory development is the difficulty in obtaining an accurate time-series of emissions from a given sector, as the mapping grids are typically only updated every few years as more survey data becomes available. The data availability limitations inevitably impact upon the

reliability of emission inventory estimates. In this study we have endeavoured to focus resources on ensuring that the most significant sources are assessed most accurately across the time series, whilst less significant source sectors may be disaggregated using a mapping grid for all years in the time series.

1.2.2.3 Other Regional Data

In recent years, the NAEI team has aimed to develop a consistent time-series of detailed datasets to inform DA and local emission inventories (back to 1990) and pollutant mapping campaigns. Examples of such datasets that have been used in this study include:

- Sub-national fuel use data for natural gas, solid fuel and petroleum-based fuels, from UK Transco (Transco, 2012), other gas network operators, the Coal Authority (Coal Authority, 2012) and the Department of Energy and Climate Change (DECC, 2012b). The UK energy mapping team has been involved in the on-going development of the DECC sub-national energy statistics which provide limited data from 2004 to 2010. These data are used to underpin many of the AQ pollutant emission estimates from small-scale (non-regulated) combustion sources such as domestic, commercial, public administration and small-scale industrial sectors. Back-casting the fuel use trends to 1990 has drawn upon available UK-level data and trends supplemented by analysis of additional data, such as Housing Condition Survey data, to ensure that significant changes are represented in the inventories (e.g. to reflect the development of the gas supply infrastructure in Northern Ireland since 1999).

- The Road Transport (1A3b) emissions database uses local traffic count data from the Department for Transport (DfT), the Northern Ireland Department of Regional Development (DRDNI), fuel use datasets (DECC), vehicle fleet data (DfT, DRDNI) and emission factors developed by TRL on behalf of DfT and from European research sources (COPERT III, IV) (EEA, 2012b) to derive detailed emission estimates for a wide range of pollutants across the UK. There were a number of changes made to the 2011 UK road transport inventory and thus affecting the DA inventories including the revision of emission factors for PM and hydrocarbon. These and other changes are described in detail in Appendix B.

- Aircraft emissions are derived from the Civil Aviation Authority's (CAA, 2012) database of flight movements, fuel use data (DECC), aircraft fleet information (CAA, 2012) and emission factors from international guidance and research (Intergovernmental Panel on Climate Change, IPCC) to derive emission estimates for aircraft cruise, take-off and landing cycles.

- Regional quarry production data and quarry location information (British Geological Survey) (BGS, 2012).

- Regional iron and steel production data, and regional fuel use data in the iron and steel industry (Tata Steel, 2012), (ISSB, 2012).

- Site-specific emissions data split by combustion and process sources for all UK refineries, and refinery production capacities (UKPIA, 2012).

- Site-specific cement production capacities and UK-wide cement industry fuel use data (British Cement Association, 2012).

- A major improvement was made to the 2011 UK rail sector emissions inventory using information from the UK's Department for Transport Rail Emissions Model (REM) and thus affecting the DA inventories. This has affected assumptions on the breakdown of fuel use between freight, intercity and regional rail, and also the emission factors used.

- Regional housing and population data (Department of Communities and Local Government).

- Regional economic activity and industrial production indices (Office of National Statistics) (ONS, 2012).

1.3 REPORT STRUCTURE

This report is structured as follows:

Main body of the report: This part of the report presents and discusses the inventories for England, Scotland, Wales and Northern Ireland, providing air quality pollutant emissions data for the years 1990, 1995, and 1998 to 2011. Emission inventories for PM_{10}, CO, NMVOCs, NH_3, NO_X, SO_2 and Pb are included in Chapter 2. Where appropriate, the reasons for any significant trends in emissions, issues regarding data availability and uncertainty estimates are provided for each inventory. A qualitative assessment of the uncertainty in the DA air quality inventories is presented in Chapter 3.

Appendix A: This appendix provides National Reporting Format (NFR) sector code descriptions.

Appendix B: This appendix provides a summary of the disaggregation methods and mapping grids used in this study, for each NFR sector.

2 Air Quality Pollutants

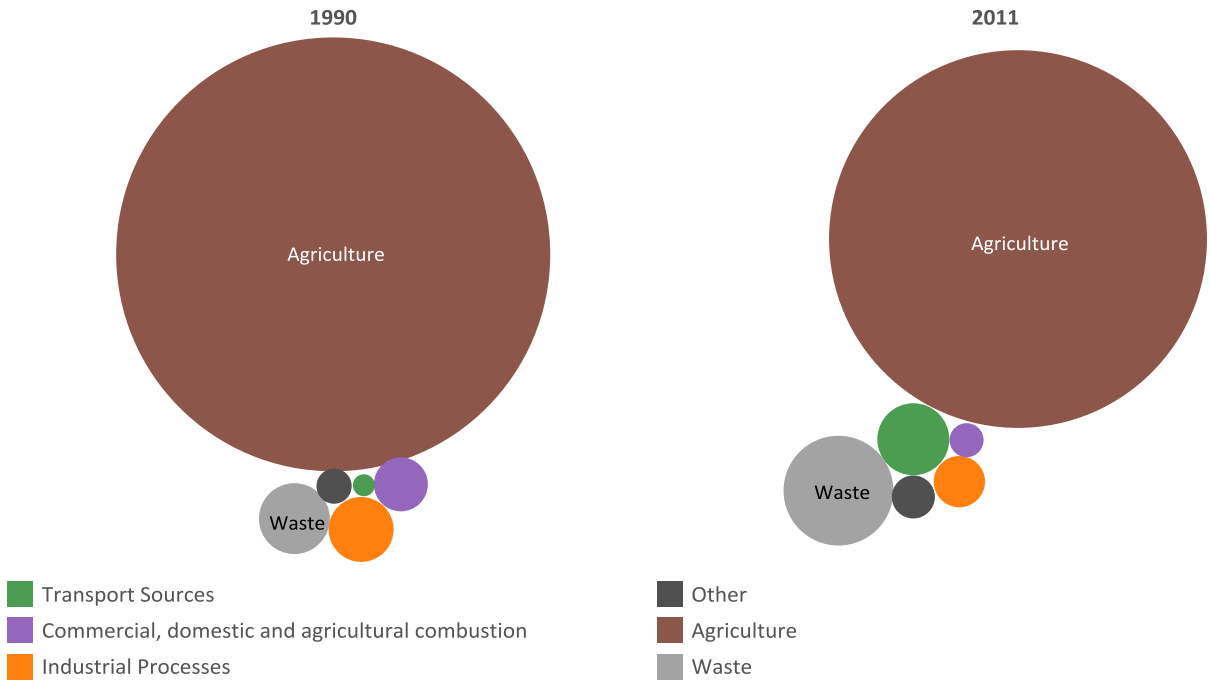
Inventories for England, Scotland, Wales and Northern Ireland for ammonia (NH_3), carbon monoxide (CO), nitrogen oxides (NO_X), non-methane volatile organic compounds (NMVOCs), sub-10 micron particulate matter (PM_{10}), sulphur dioxide (SO_2) and lead (Pb) are discussed in the following sections. These data have been derived by disaggregation of the UK figures using point source, mapping and regional datasets as appropriate (see Appendix B for details).

2.1 AMMONIA

Ammonia (NH_3) emissions play an important role in a number of different environmental issues including acidification, eutrophication and changes in biodiversity. The atmospheric chemistry of NH_3 and NH_4^+ is such that transport of the pollutants can vary greatly, and that as a result, NH_3 emissions can exert impacts on a highly localised level, as well as contributing to the effects of long-range pollutant transport.

UK emission estimates of ammonia are presented below for 1990 and 2011. UK ammonia emissions have decreased by 18% since 1990 as indicated by the change in area between the 1990 and 2011 graphs (**Figure 2-1**).

Figure 2-1 UK Ammonia Emissions by Sector (1990 and 2011)



The main source of ammonia emissions in the UK is livestock manure management, and in particular cattle manure management. These emissions derive mainly from the decomposition of urea in animal wastes and uric acid in poultry wastes. Emissions from nitrogen fertiliser use on grassland and arable crops are also a significant source and included in the ammonia inventory.

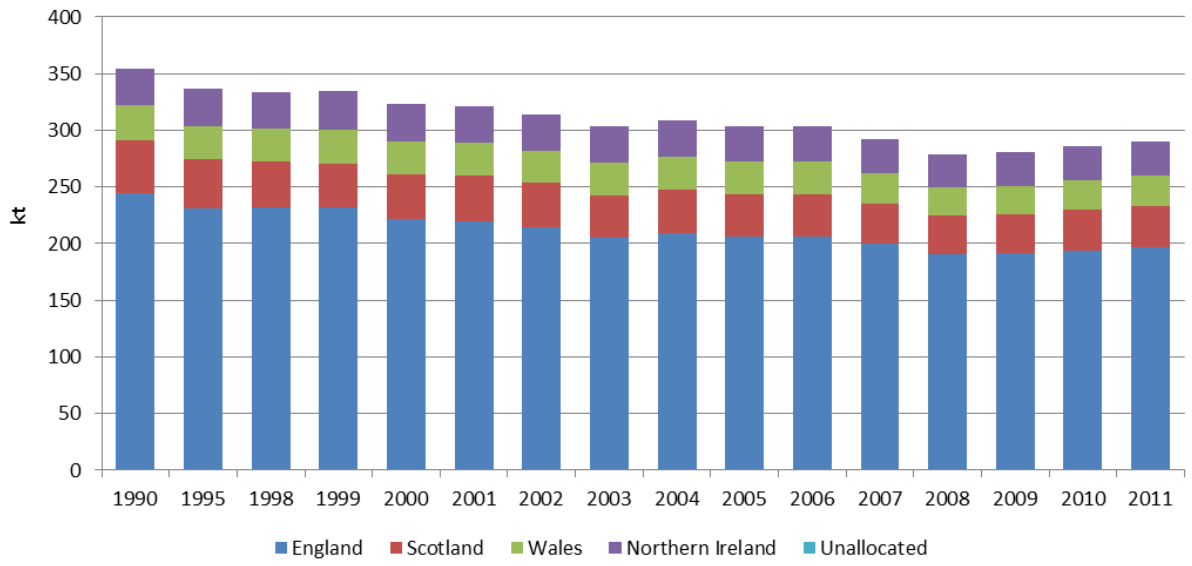
Emissions are affected by a large number of factors, including animal species, age, weight, diet, housing and manure management systems, and environmental conditions. As such, the interpretation and extrapolation of experimental data is problematic, making emission estimates uncertain. Estimates are based on official

livestock datasets, annual fertiliser use surveys, farm management practice surveys and detailed emission factors from recent literature sources. The methodology for compiling the inventory of ammonia emissions from agriculture follows that of Webb and Misselbrook (2004) for manure management sources and Misselbrook et al (2004) for fertiliser sources, with annual revisions to input data, emission factors and other parameters as described in the annual Informative Inventory Report.

Decreasing livestock numbers (cattle in particular) and fertiliser use in the UK since 1990 have led to reductions in UK ammonia emissions, and it is this trend in agricultural sources that influences the DA-level inventories most significantly until 2008. As seen in **Figure 2-2** below, there has been a steady increase in emissions since 2008. This is because ammonia emission estimates from anaerobic digestion have been included in the UK and DA inventories for the first time in the 1990-2011 dataset, reported under Waste (other). The activity for anaerobic digestion in the UK has increased 15-fold between 2008 and 2011 alone.

Non-agricultural sources of ammonia comprise a number of diverse sources. Emission estimates for these sources are often highly uncertain due to a lack of activity and emission factor data. Emissions from road transport (although relatively insignificant compared to agricultural emissions) increased in the 1990's as a result of the increasing number of three way catalysts in the vehicle fleet. However, emissions are now falling as the second generation of catalysts (which lead to lower ammonia emissions than first generation catalysts) penetrates the vehicle fleet.

Figure 2-2 UK Ammonia Emissions by Devolved Administration, 1990-2011



Emissions of ammonia for England, Wales, Scotland and Northern Ireland are summarised in the tables and graphs below. **Table 2-1** shows how the estimated total UK ammonia emissions are split between the four Devolved Administrations and **Table 2-2** show emissions of ammonia per capita, with a comparison against the average for the UK.

Table 2-1 Proportion of UK Ammonia Emissions by Devolved Administration

Year	England	Scotland	Wales	Northern Ireland	Unallocated
1990	69%	13%	9%	9%	0%
2011	68%	13%	9%	10%	0%

Table 2-2 Emissions of Ammonia per capita by Devolved Administration and the UK (kg/head)

Year	England	Scotland	Wales	Northern Ireland	UK
1990	5.1	9.2	10.8	20.3	6.2
2011	3.7	6.9	8.7	16.8	4.6

2.1.1 England Ammonia Inventory by Sector, 1990-2011

The table and graph below give a summary of the ammonia emissions in England by broad NFR sector categories. The disaggregation of these categories is available in Appendix A (see Sector Category column).

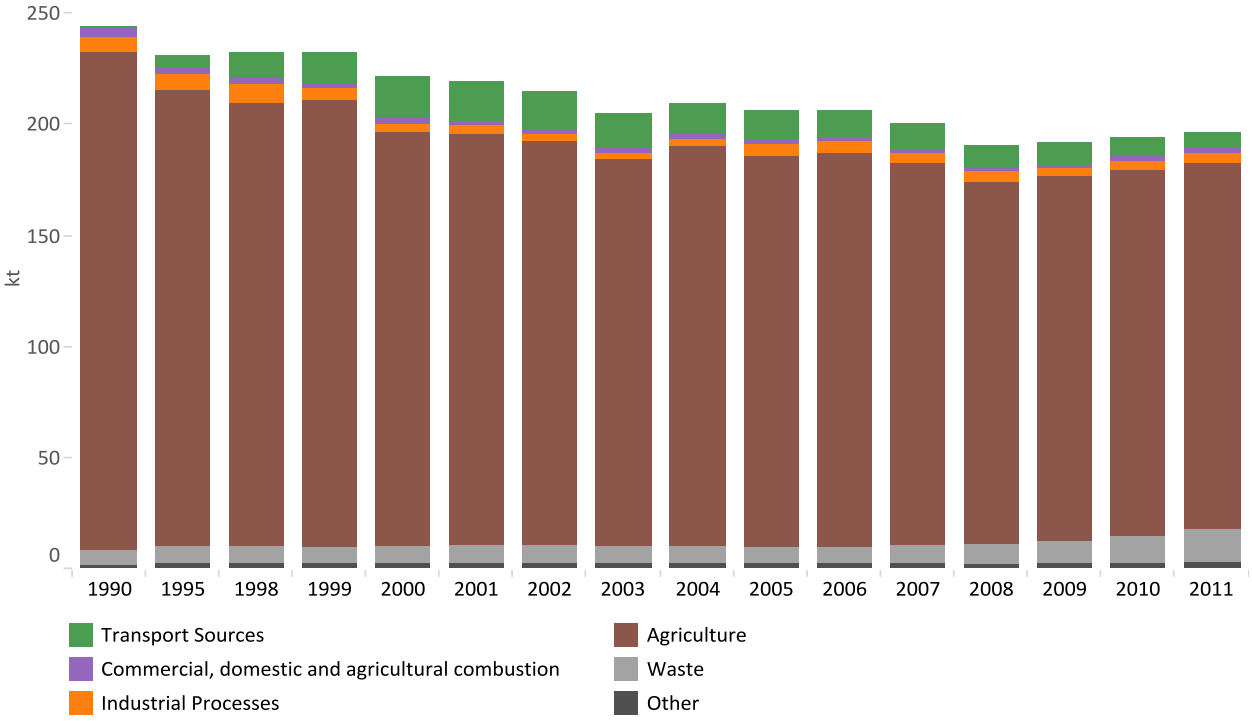
Table 2-3 England Emissions of Ammonia by Sector, 1990-2011

	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Transport Sources	0.7	5.8	11.5	13.3	19.2	17.9	16.7	15.2	14.2	13.1	12.2	11.2	9.9	9.5	8.4	7.5
Commercial, domestic and agricultural combustion	3.2	2.2	2.0	2.1	1.7	1.7	1.3	1.2	1.1	1.0	0.9	1.0	1.1	1.1	1.2	1.3
Industrial Processes	7.1	7.2	8.8	4.8	3.5	3.6	3.5	3.2	3.1	5.3	5.0	4.7	4.2	4.0	3.8	4.5
Agriculture	224.6	206.1	200.1	202.0	187.1	186.1	182.8	175.0	181.2	176.8	177.7	172.6	164.1	164.7	165.6	166.1
Waste	6.9	8.2	7.9	8.0	8.0	8.1	8.1	8.0	7.8	7.8	7.9	8.2	8.5	10.1	12.5	14.7
Other [1]	1.8	2.0	2.0	2.1	2.2	2.3	2.3	2.2	2.2	2.2	2.4	2.4	2.5	2.3	2.4	2.7
Total	**244**	**231**	**232**	**232**	**222**	**220**	**215**	**205**	**210**	**206**	**206**	**200**	**190**	**192**	**194**	**197**

Units: kilotonnes

[1] "Other" for ammonia includes emissions from Energy Industries, Industrial Combustion, Fugitive, Solvent Processes, as well as 1A5b, 7A.

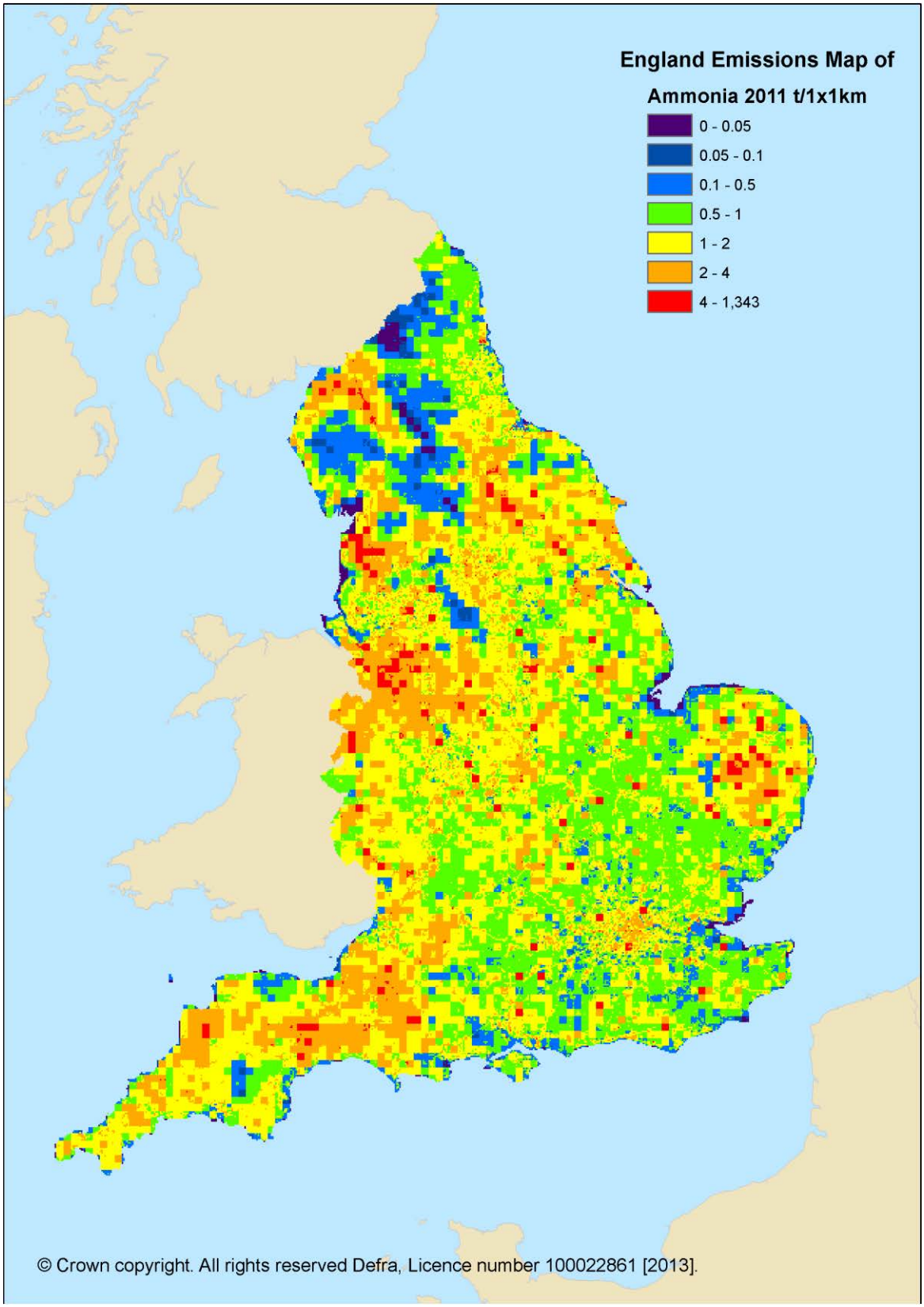
Figure 2-3 England Ammonia Emissions by Sector, 1990-2011



Ammonia emissions in England have declined by 19% since 1990 and currently account for 68% of the UK total. The inventory is dominated by emissions from agricultural sources with manure management accounting for 61% of the total in 2011. 33% of the English total is from cattle manure management alone (down 21% since 1990). Other sources of note include waste emissions (7% of the England total in 2011), which have increased by 74% since 2008 primarily due to the increase in emissions from composting and anaerobic digestion, and transport emissions (4% of the England total in 2011). This sector is the predominant cause of the upward trend of emissions seen from 2008 to 2011 (increase of 3%).

English ammonia emissions per capita are much lower than the UK average. This is mostly due to the smaller contribution of emissions from agriculture in England; English emissions from this sector account for 68% of UK emissions in 2011 for the sector, which is much lower than England's contribution to the population (84%).

Figure 2-4 Map of Ammonia Emissions in England, 2011



2.1.2 Scotland Ammonia Inventory by Sector, 1990-2011

The table and graph below give a summary of the ammonia emissions in Scotland by broad NFR sector categories. The disaggregation of these categories is available in Appendix A (see Sector Category column).

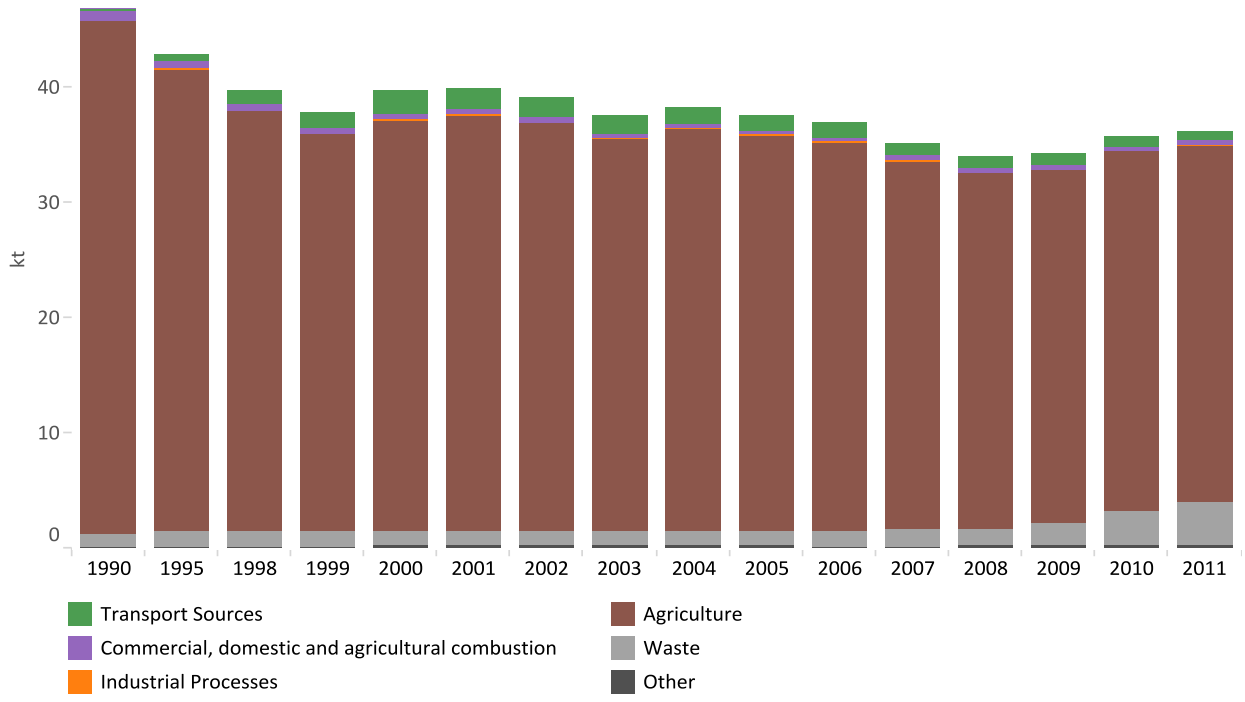
Table 2-4 Scotland Emissions of Ammonia by Sector, 1990-2011

	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Transport Sources	0.1	0.6	1.2	1.3	2.0	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.0	1.0	0.9	0.8
Commercial, domestic and agricultural combustion	0.8	0.4	0.4	0.4	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3
Industrial Processes	0.07	0.08	0.08	0.07	0.07	0.07	0.06	0.06	0.07	0.08	0.06	0.07	0.06	0.06	0.06	0.09
Agriculture	44.7	40.3	36.7	34.6	35.9	36.3	35.6	34.2	35.2	34.5	33.9	32.2	30.9	30.7	31.4	31.2
Waste	1.1	1.3	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.3	1.3	1.4	2.0	3.0	3.7
Other [1]	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Total	**47**	**43**	**40**	**38**	**40**	**40**	**39**	**38**	**38**	**38**	**37**	**35**	**34**	**34**	**36**	**36**

Units: kilotonnes

[1] "Other" for ammonia includes emissions from Energy Industries, Industrial Combustion, Fugitive, Solvent Processes as well as 1A5b, 7A.

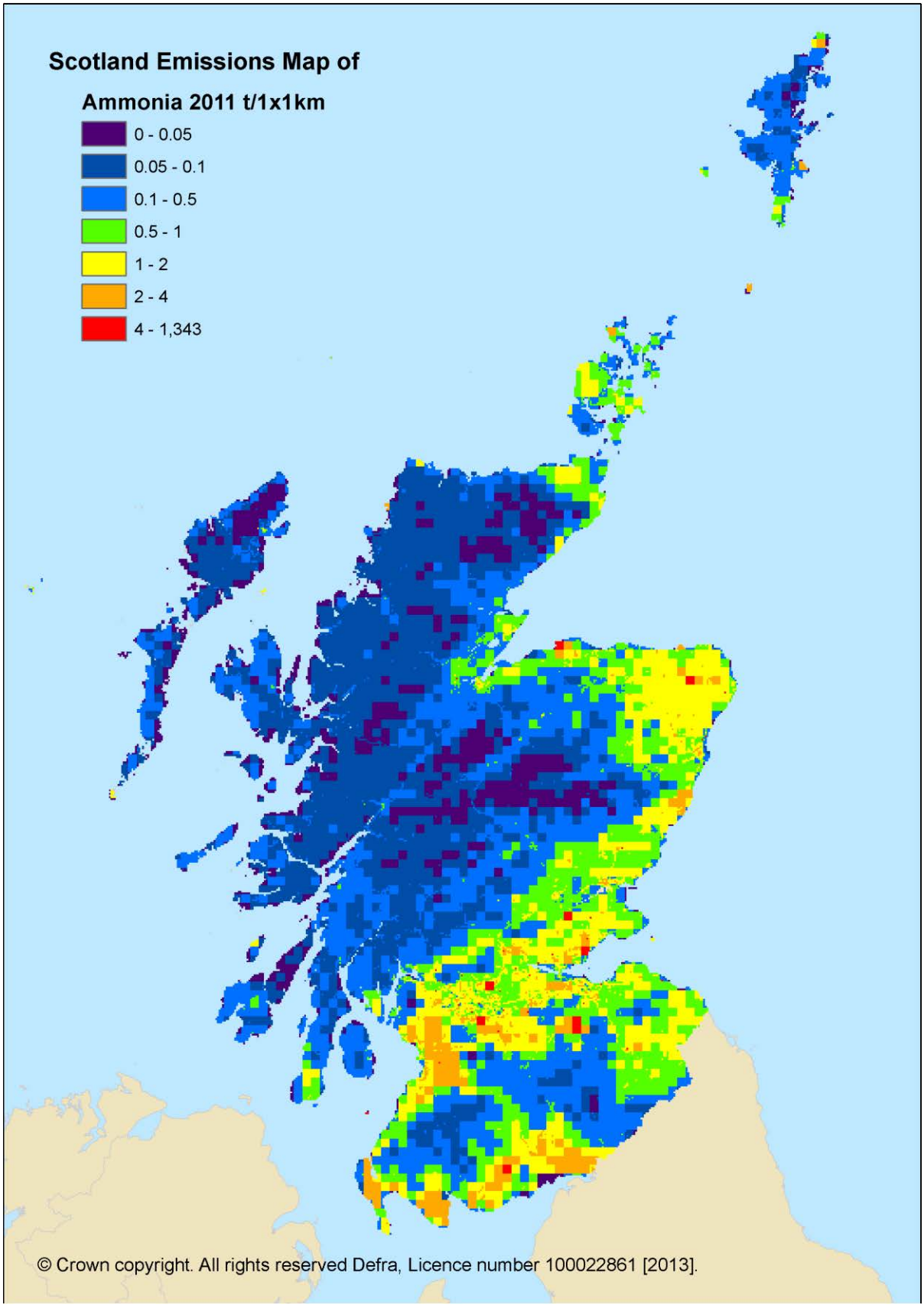
Figure 2-5 Scotland Ammonia Emissions by Sector, 1990-2011



Ammonia emissions in Scotland have declined by 23% since 1990 and accounted for 13% of the UK total in 2011. The inventory is dominated by emissions from agricultural sources with manure management account for 65% of the total in 2011 (down 11% since 1990). Other sources of note include emissions from waste (10% of the Scotland total in 2011), which have increased by 155% since 2008 primarily due to the increase in emissions from composting and anaerobic digestion, and transport emissions (2% of the Scotland total in 2011). This sector is the predominant cause of the upward trend of emissions seen from 2008 to 2011 (increase of 7%). Scotland has a higher share of the UK agriculture sector activity than it does of the UK

population, and hence the per capita emissions of ammonia are slightly higher in Scotland than the UK average in 2011.

Figure 2-6 Map of Ammonia Emissions in Scotland, 2011



2.1.3 Wales Ammonia Inventory by Sector, 1990-2011

The table and graph below give a summary of the ammonia emissions in Wales by broad NFR sector categories. The disaggregation of these categories is available in Appendix A (see Sector Category column).

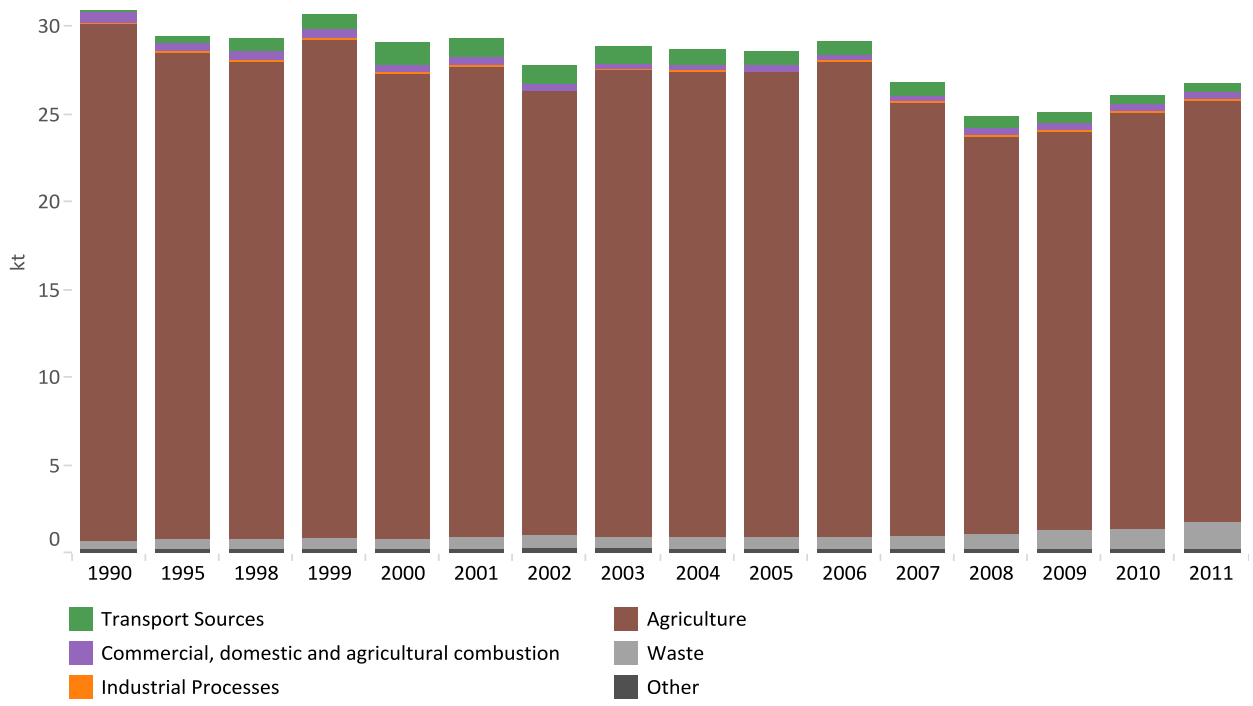
Table 2-5 Wales Emissions of Ammonia by Source, 1990-2011

	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Transport Sources	0.0	0.4	0.7	0.8	1.2	1.1	1.1	1.0	0.9	0.8	0.8	0.7	0.6	0.6	0.5	0.5
Commercial, domestic and agricultural combustion	0.6	0.5	0.4	0.4	0.4	0.4	0.3	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3
Industrial Processes	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.05	0.05	0.07	0.07	0.06	0.05	0.06	0.06
Agriculture	29.5	27.8	27.3	28.5	26.6	26.9	25.4	26.7	26.7	26.6	27.1	24.8	22.8	22.9	23.9	24.1
Waste	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.7	0.7	0.8	0.9	1.1	1.2	1.6
Other [1]	0.15	0.16	0.16	0.18	0.17	0.24	0.29	0.26	0.21	0.18	0.19	0.18	0.19	0.16	0.16	0.21
Total	**31**	**29**	**29**	**31**	**29**	**29**	**28**	**29**	**29**	**29**	**29**	**27**	**25**	**25**	**26**	**27**

Units: kilotonnes

[1] "Other" for ammonia includes emissions from Energy Industries, Industrial Combustion, Fugitive, Solvent Processes as well as 1A5b, 7A.

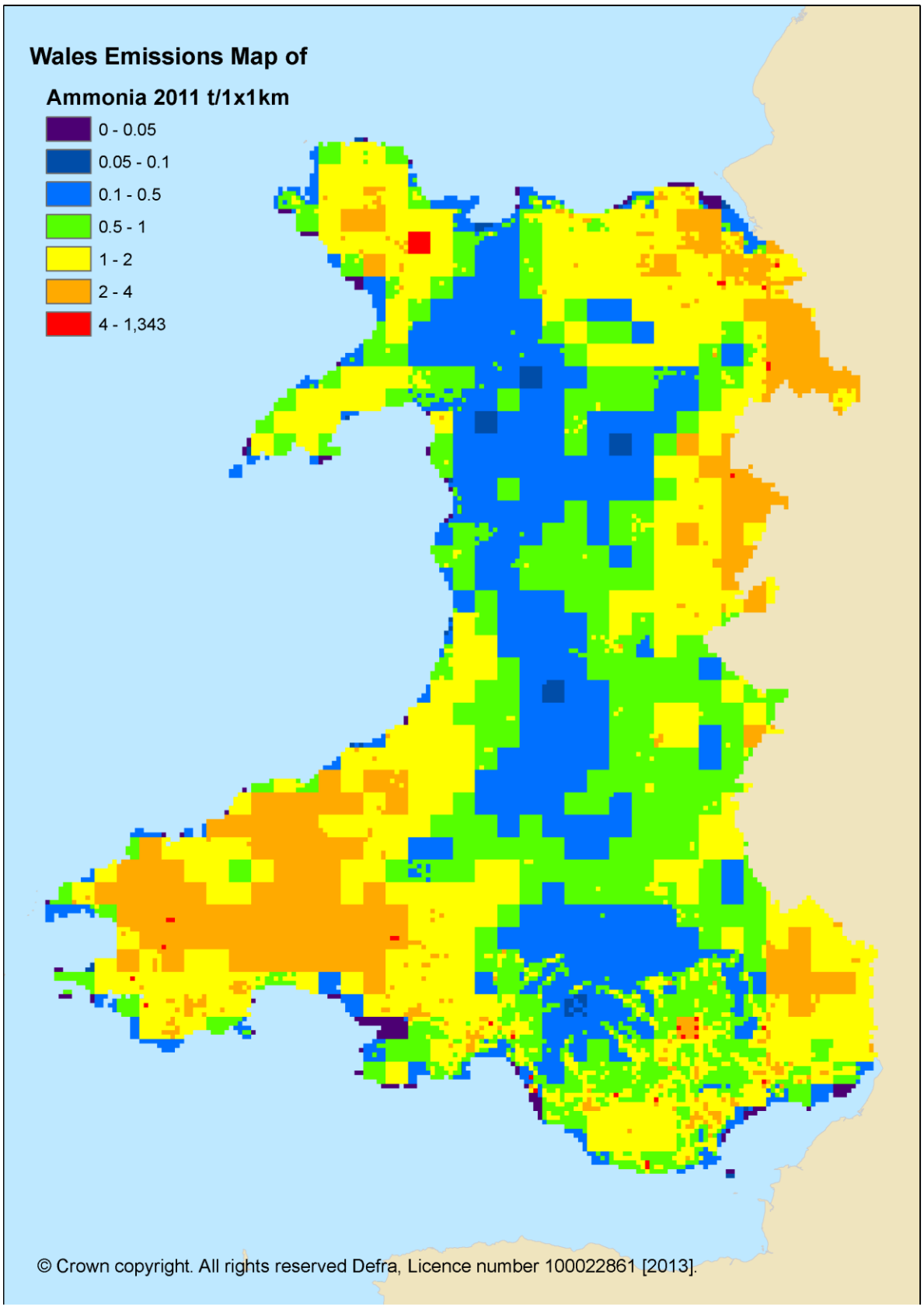
Figure 2-7 Wales Ammonia Emissions by Sector, 1990-2011



Ammonia emissions in Wales have declined by 14% since 1990 and accounted for 9% of the UK total in 2011. The inventory is dominated by emissions from agricultural sources with 65% of the total in 2011 coming from manure management. In 2011, 49% of emissions from Wales are estimated to originate from cattle manure management alone (down 12% since 1990). Other sources of note include transport emissions (2% of the Wales total in 2011) and waste (6% of the Wales total in 2011).

Emissions from the waste sector and agriculture sector have increased between 2008 and 2011 resulting in a steady increase (8%) of total ammonia emissions over this time period. This was primarily due to the increase in emissions from N-fertilizers and composting since 2008. Wales has a higher share of the UK agriculture sector activity than it does of the UK population, and hence the per capita emissions of ammonia are slightly higher in Wales than the UK average in 2011.

Figure 2-8 Map of Ammonia Emissions in Wales, 2011



2.1.4 Northern Ireland Ammonia Inventory by Sector, 1990-2011

The table and graph below give a summary of the ammonia emissions in Northern Ireland by broad NFR sector categories. The disaggregation of these categories is available in Appendix A (see Sector Category column).

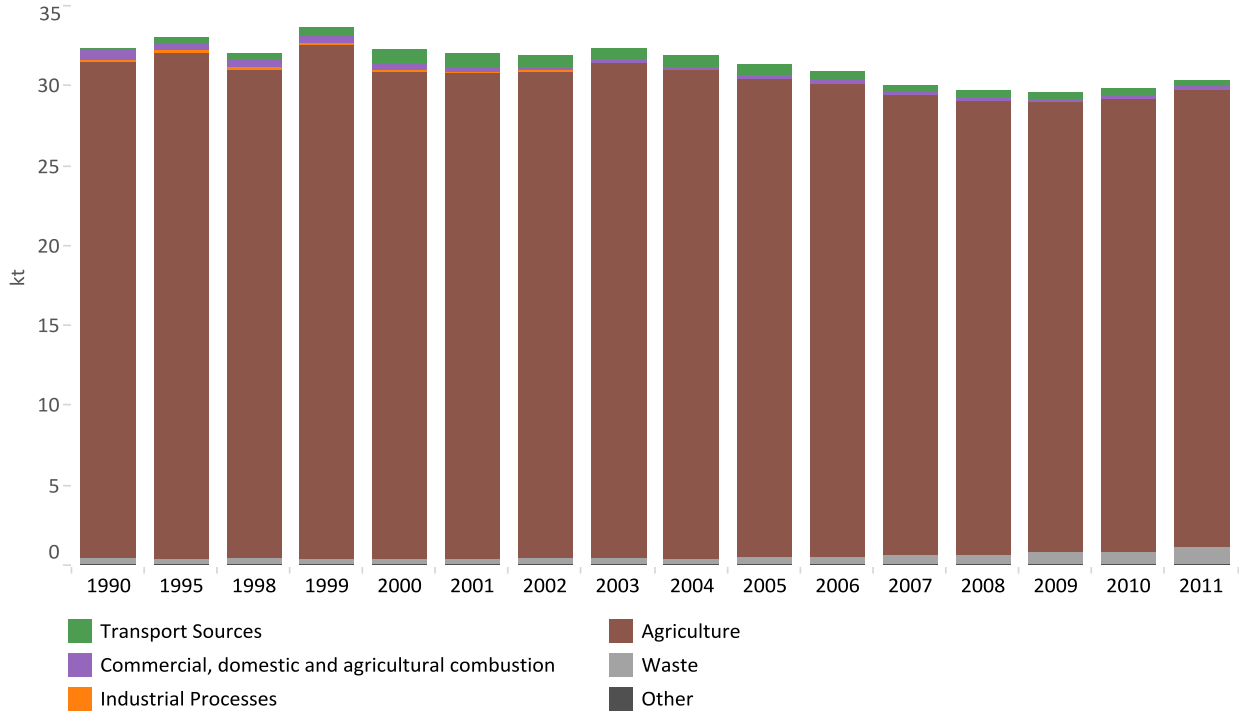
Table 2-6 Northern Ireland Emissions of Ammonia by Sector, 1990-2011

	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Transport Sources	0.0	0.3	0.5	0.6	0.9	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4
Commercial, domestic and agricultural combustion	0.6	0.4	0.3	0.3	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Industrial Processes	0.16	0.16	0.16	0.16	0.16	0.16	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agriculture	31.2	31.7	30.7	32.2	30.5	30.4	30.6	31.1	30.7	30.1	29.7	28.9	28.5	28.2	28.4	28.7
Waste	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.6	0.7	0.8	1.1
Other [1]	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	**32.3**	**33.0**	**32.1**	**33.7**	**32.3**	**32.1**	**32.0**	**32.4**	**31.9**	**31.3**	**30.9**	**30.1**	**29.8**	**29.6**	**29.8**	**30.3**

Units: kilotonnes

[1] "Other" for ammonia includes emissions from Energy Industries, Industrial Combustion, Fugitive, Solvent Processes as well as 1A5b, 7A.

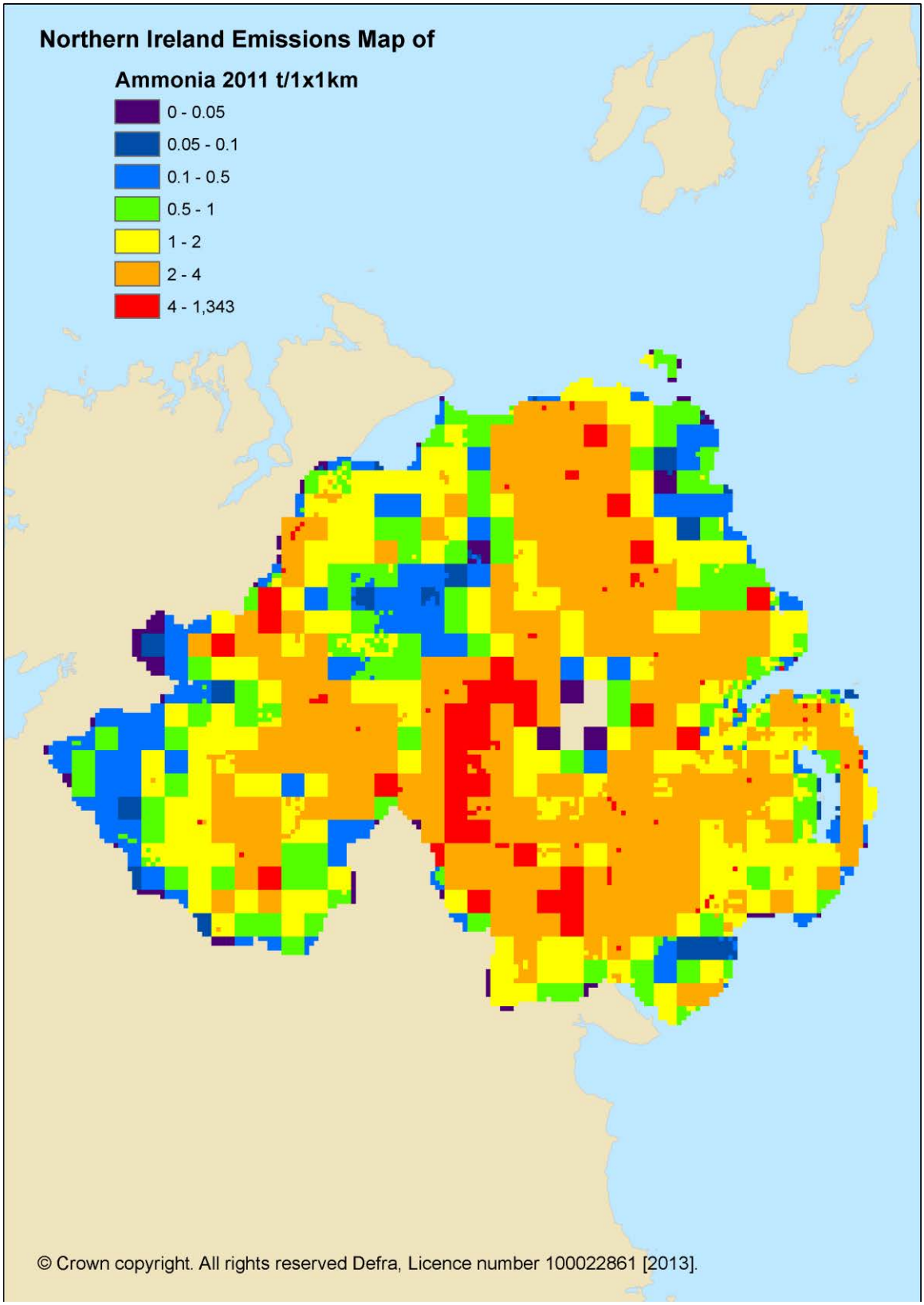
Figure 2-9 Northern Ireland Ammonia Emissions by Sector, 1990-2011



Ammonia emissions in Northern Ireland have declined by 6% since 1990 and currently account for 10% of the UK total. The inventory is dominated by emissions from agricultural sources with 80% of the total in 2011 coming from manure management. In 2011, 59% of the Northern Ireland total is from cattle manure management alone (up 12% since 1990). Waste emissions (4% of the Northern Ireland total in 2011) have increased by 90% since 2008 primarily due to an increase in emissions from composting and anaerobic digestion. Increased emissions from composting are the predominant cause of the upward trend seen from 2008 to 2011 (increase of 2%). Other sources of note include transport emissions (1% of the Northern Ireland total in 2011).

Per capita emissions for Northern Ireland are over three times the UK average in 2011. This is mostly due to the high emissions from agricultural sources, where Northern Ireland contributed 10% to the total UK emission for this sector, compared with only 3% of the UK population.

Figure 2-10 Map of Ammonia Emissions in Northern Ireland, 2011

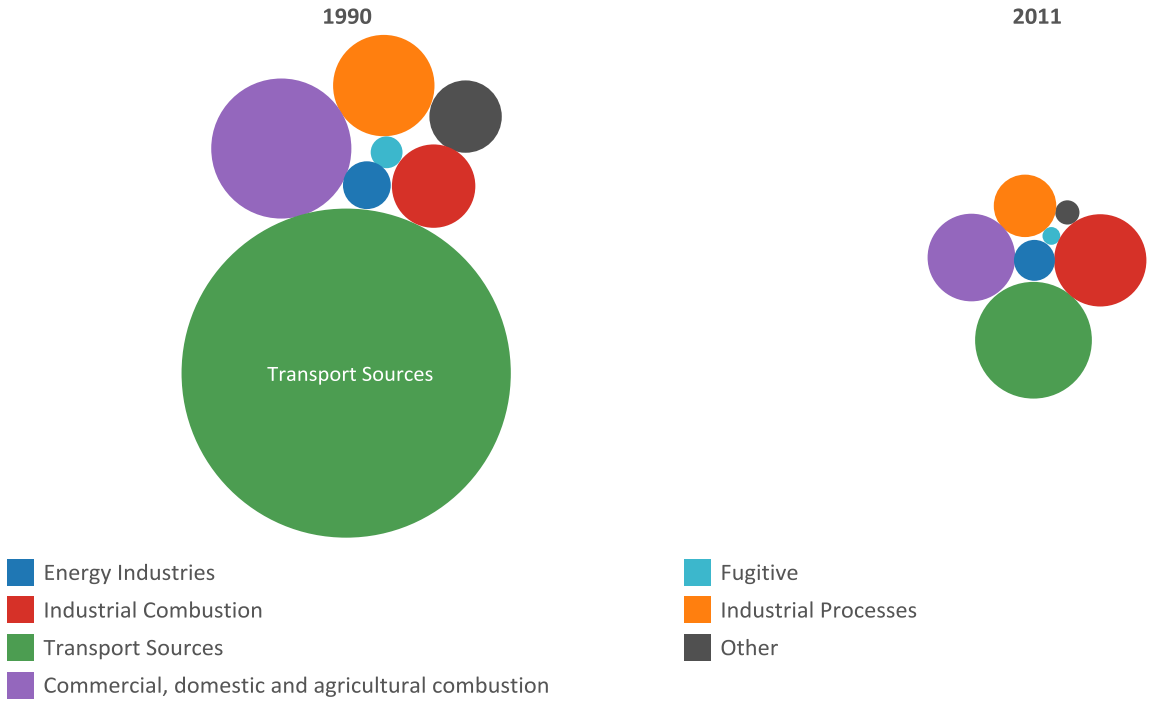


2.2 CARBON MONOXIDE

Carbon monoxide (CO) arises from incomplete fuel-combustion and is of concern mainly due to its toxicity and its role in tropospheric ozone formation. In terms of human health, carbon monoxide combines with haemoglobin in blood, decreasing the uptake of oxygen by the lungs, with symptoms varying from nausea to asphyxiation depending upon the level of exposure.

UK emission estimates for carbon monoxide are presented below for 1990 and 2011 (**Figure 2-11**). UK emissions have decreased by 76% between 1990 and 2011 as indicated by the change in area between the 1990 and 2011 graph.

Figure 2-11 UK Carbon Monoxide Emissions by Sector (1990 and 2011)



The decline in carbon monoxide emissions since 1990 has been driven by reductions in emissions from a number of sources, including road transport, agricultural field burning and the domestic sector. The decrease is dominated by the reduction in emissions from the road transport sector, caused by the increased use of three-way catalysts in cars; this trend is evident for all DAs. The main sources of carbon monoxide are outlined below:

- **Road transport –** petrol engines are the main source of carbon monoxide emissions, especially from cold start engine cycles. Since 1990, emissions from road transport sources have reduced by 88% due to the development of more efficient engine combustion technology, the increased use of catalytic converters and the growth in diesel engine use. Between 2008 and 2011 emissions from passenger cars decreased by 51% due to an improvement in catalyst replacement rates, coupled with a downturn in vehicle km travelled.

- **Non road mobile machinery** – in the UK, 14% of carbon monoxide emissions in 2011 came from off-road mobile industrial, domestic and agricultural machinery such as portable generators, forklift trucks, lawnmowers and tractors. Emissions are calculated using a complex model which takes into account the population of machinery in the UK, annual usage, the engine size, replacement rates, and the implementation of legislation aimed at reducing emissions. The population of machinery within the model is based on an in depth survey for 2004, with the time series generated using proxy statistics. As such, these estimates are relatively uncertain, however a comparison of the UK's non

road mobile machinery emissions in 2010 with those of other EU Member States indicated that the emissions are within the expected range for the UK.

- **Stationary domestic combustion** –in 2011, 15% of carbon monoxide emissions in the UK came from domestic combustion sources, namely non-electric domestic heating. Reductions in emissions have been significant, due to the switch from solid fuels to the use of gas and electricity, with a 69% reduction in UK emissions since 1990.

Other sources of carbon monoxide emissions are small compared with transport and off-road sources. Industrial combustion emissions decreased by 23% between 1990 and 2011, reflecting fuel switching from solid fuels to gas, similar to the domestic sector. The increase between 2009 and 2010 of 11% reflects the cold weather experienced in 2010 and further increases in 2011 reflect increases in recent years in biomass use in industrial combustion, emissions from which have increased four-fold since 2008. The sudden decline in emissions from the "other" sector reflects the banning of agricultural stubble burning in 1993 in England and Wales.

Emissions of carbon monoxide for England, Wales, Scotland and Northern Ireland are summarised in the tables and graphs below. **Figure 2-12** shows the split of emissions between the four Devolved Administrations for the entire time series with **Table 2-7** presenting this split as a percentage for 1990 and 2011. **Table 2-8** shows per capita emissions for 1990 and 2011.

Figure 2-12 UK Carbon Monoxide Emissions by Devolved Administration, 1990-2011

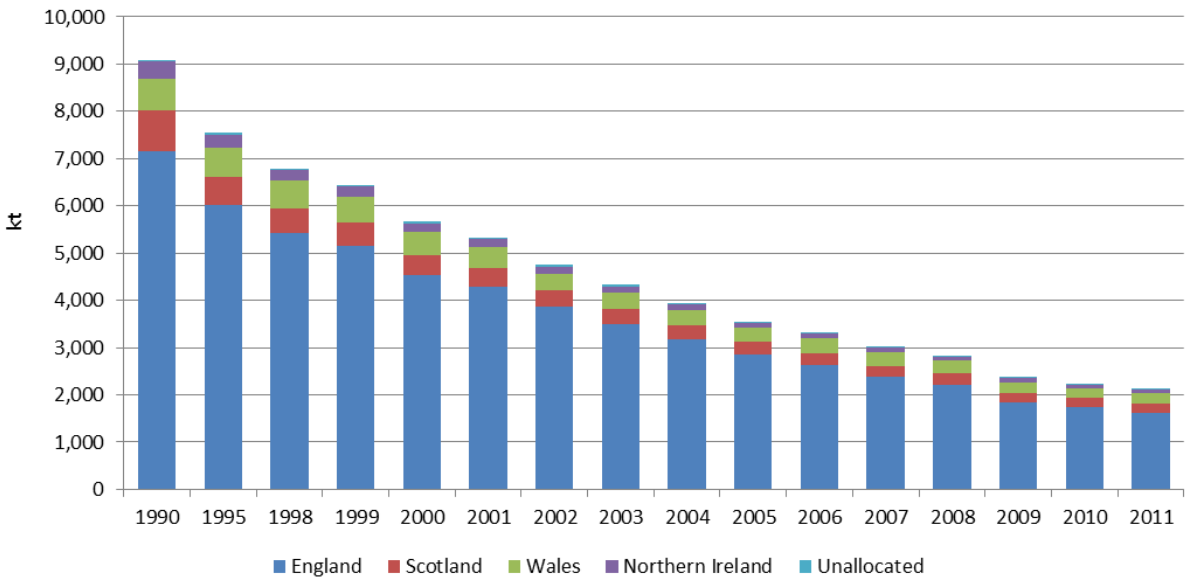


Table 2-7 Proportion of UK Carbon Monoxide Emissions by Devolved Administration

Year	England	Scotland	Wales	Northern Ireland	Unallocated
1990	79%	10%	7%	4%	0%
2011	76%	9%	11%	4%	1%

Table 2-8 Emissions of Carbon Monoxide per capita by Devolved Administration (kg/head)

Year	England	Scotland	Wales	Northern Ireland	UK
1990	149.9	172.5	234.0	223.0	158.7
2011	30.6	35.5	73.5	47.4	33.9

2.2.1 England Carbon Monoxide Inventory by Sector, 1990-2011

The table and graph below give a summary of the carbon monoxide emissions in England by broad NFR sector categories. The disaggregation of these categories is available in Appendix A (see Sector Category column).

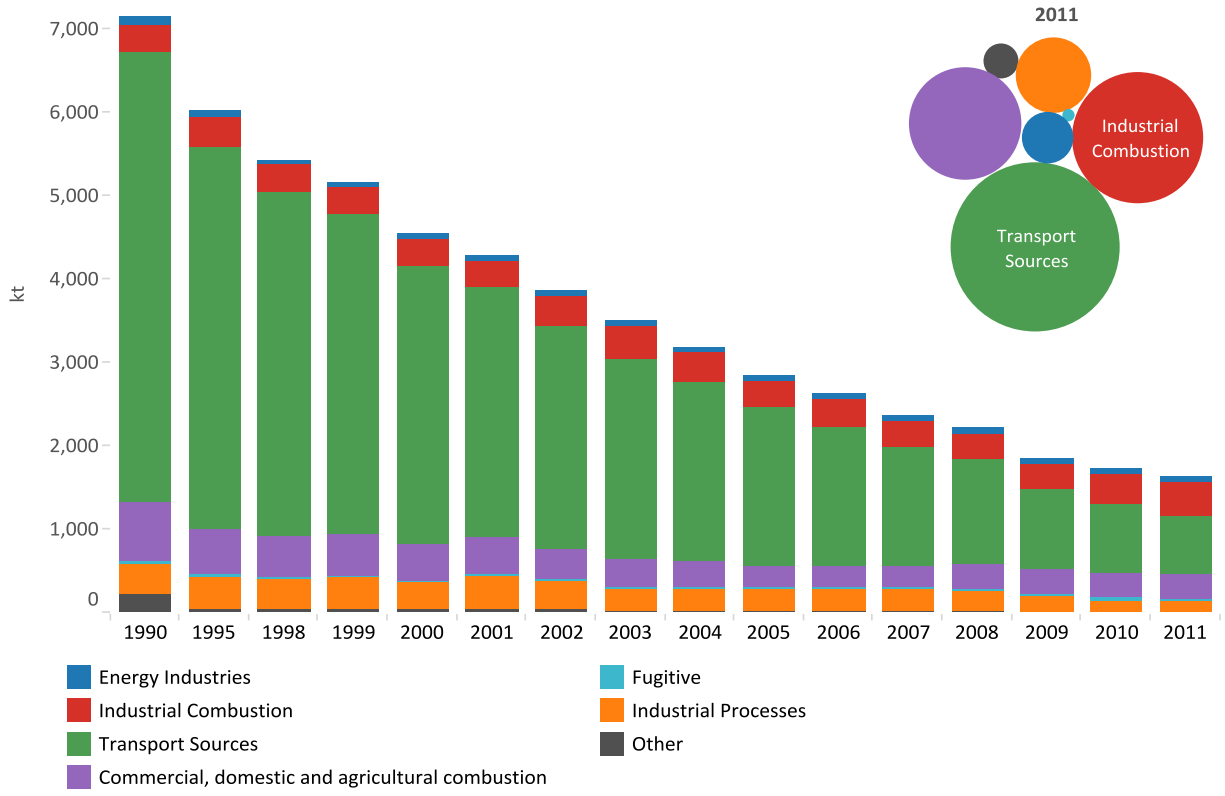
Table 2-9 England Emissions of Carbon Monoxide by Sector, 1990-2011

	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Energy Industries	99	93	56	51	60	58	57	64	62	67	67	68	69	60	61	63
Industrial Combustion	325	345	330	325	308	314	352	400	351	323	332	328	314	308	364	410
Transport Sources	5,398	4,590	4,132	3,835	3,340	3,016	2,690	2,399	2,152	1,887	1,663	1,409	1,266	963	821	682
Commercial, domestic and agricultural combustion	701	540	489	502	432	434	361	326	315	272	259	270	289	288	315	302
Fugitive	22	13	13	11	11	6	5	7	5	5	5	5	5	4	4	4
Industrial Processes	391	416	381	401	356	408	363	272	262	262	263	259	247	191	137	136
Other [1]	213	33	31	32	31	47	32	32	31	30	32	32	30	30	29	29
Total	**7,149**	**6,029**	**5,432**	**5,156**	**4,536**	**4,285**	**3,860**	**3,500**	**3,178**	**2,845**	**2,621**	**2,372**	**2,219**	**1,844**	**1,731**	**1,625**

Units: kilotonnes

[1] "Other" for carbon monoxide includes emissions from Solvent Processes, Agriculture, Waste as well as 1A5b, 7A.

Figure 2-13 England Carbon Monoxide Emissions by Sector, 1990-2011

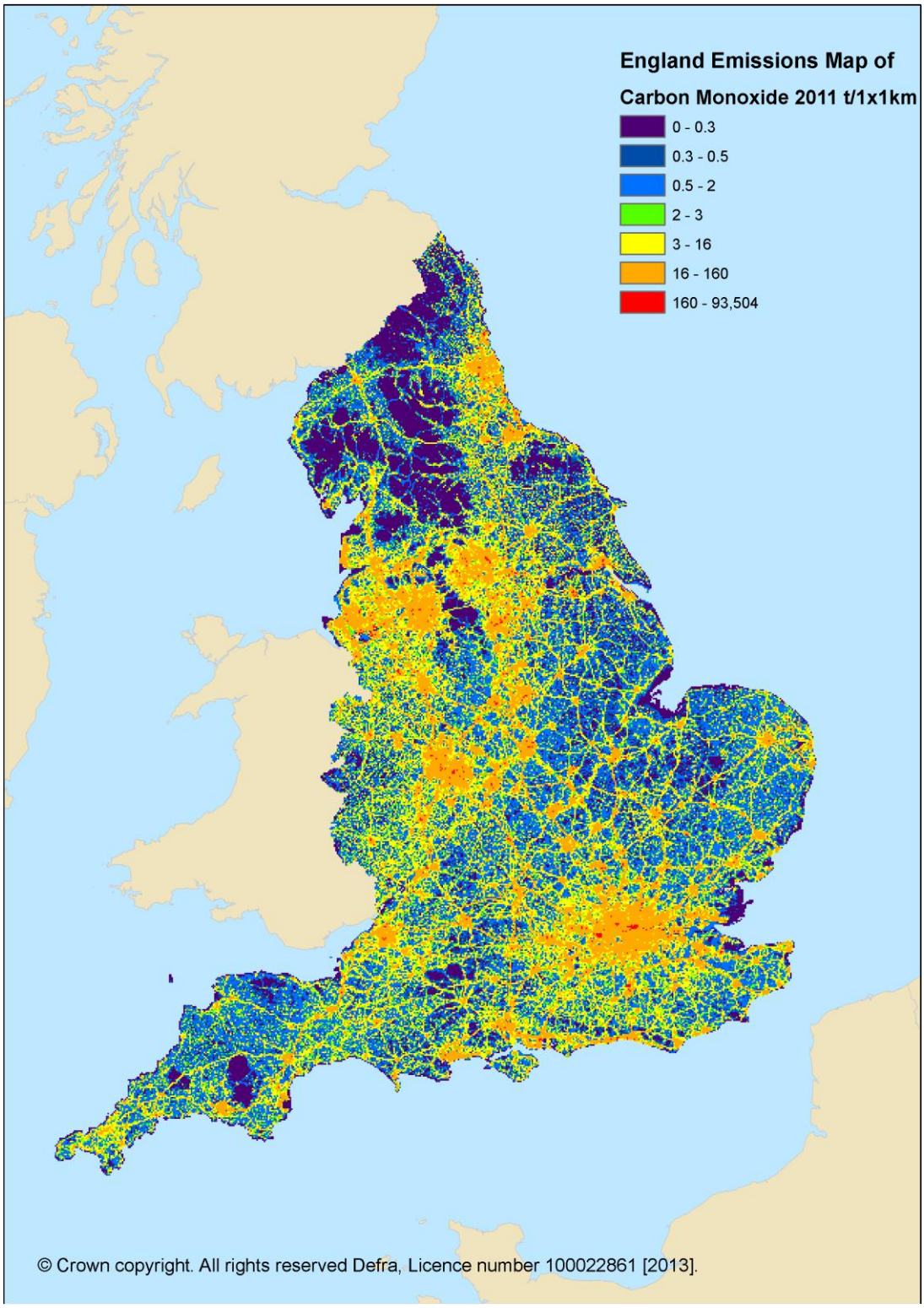


Carbon monoxide emissions in England have declined by 77% since 1990 and account for 76% of the UK total. In 2011, 38% of CO emissions in England stem from road transport combustion sources (down by 88% since 1990), whilst 25% stem from industrial combustion (up 26% since 1990) and 19% from commercial, domestic and agricultural combustion (down 57% since 1990). The increase in industrial emissions is driven in recent

years by an upturn in biomass use for industrial combustion, which has more than doubled in England since 2005.

Between 2010 and 2011, emissions of CO in England have declined by 6%. This declining trend is driven by the decline in emissions from passenger cars due to improved catalyst replacement rates (down 20% between 2010 and 2011), partly offset by increasing emissions from industrial combustion due to the upturn in biomass fuel use.

Figure 2-14 Map of Carbon Monoxide Emissions in England, 2011



2.2.2 Scotland Carbon Monoxide Inventory by Sector, 1990-2011

The table and graph below give a summary of the carbon monoxide emissions in Scotland by broad NFR sector categories. The disaggregation of these categories is available in Appendix A (see Sector Category column).

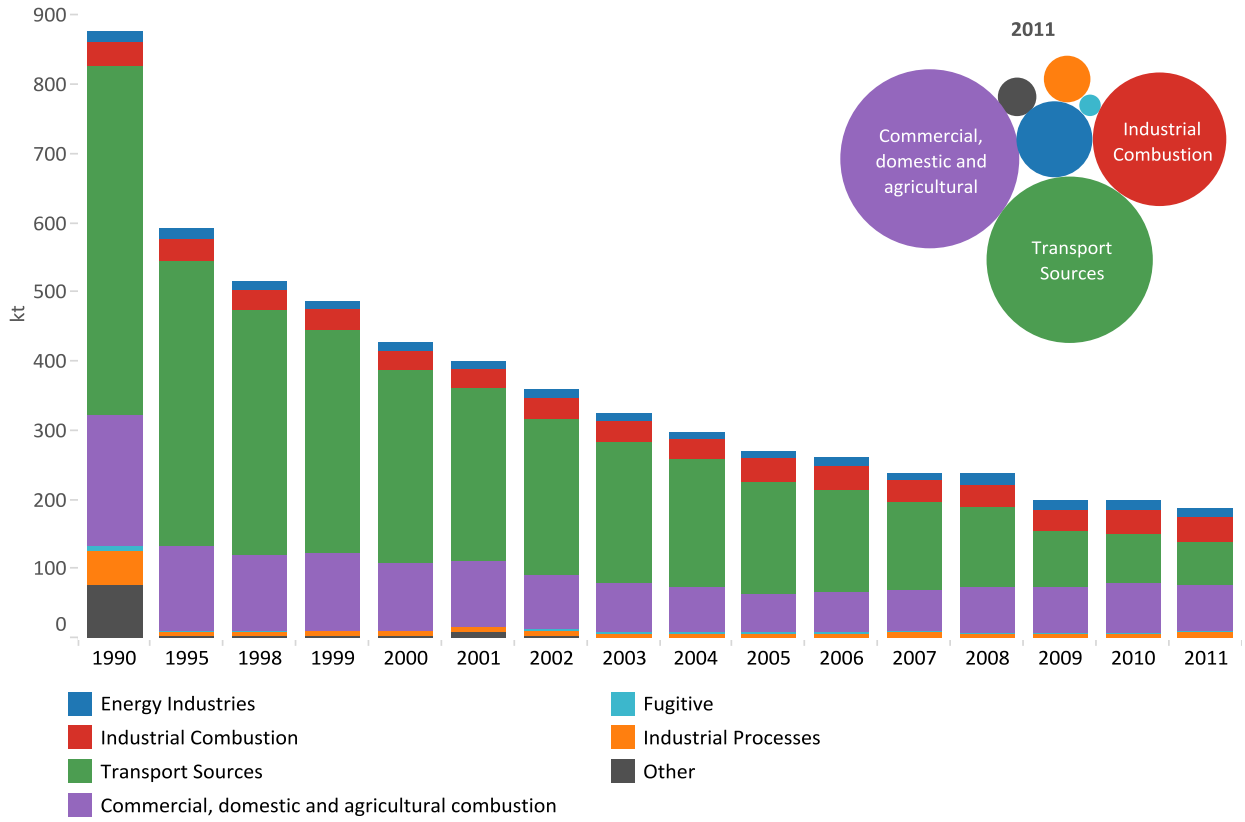
Table 2-10 Scotland Emissions of Carbon Monoxide by Sector, 1990-2011

	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Energy Industries	15.0	15.0	10.3	9.7	11.5	11.2	10.7	9.9	10.4	10.2	12.1	11.5	15.7	15.1	14.7	12.3
Industrial Combustion	34.7	31.6	29.9	31.0	27.2	27.9	30.4	32.6	29.9	32.8	32.5	31.8	32.9	29.6	33.9	38.1
Transport Sources	506.5	411.8	354.6	323.1	280.3	251.5	225.2	202.8	184.4	163.3	148.3	126.6	114.9	81.4	70.3	59.1
Commercial, domestic and agricultural combustion	188.4	122.4	109.4	110.6	95.8	93.1	79.3	70.7	64.7	55.3	57.7	60.2	65.5	64.5	71.4	68.4
Fugitive	5.1	1.1	1.0	1.2	1.1	1.7	1.2	0.9	0.9	1.0	0.8	1.0	0.9	0.9	0.9	1.0
Industrial Processes	50.3	5.4	5.8	6.7	6.9	7.0	7.2	3.7	3.7	3.6	4.3	4.4	4.3	3.8	4.2	4.6
Other [1]	76.7	3.6	3.4	3.4	3.3	7.5	3.4	3.5	3.4	3.3	3.5	3.5	3.3	3.2	3.2	3.2
Total	**877**	**591**	**514**	**486**	**426**	**400**	**357**	**324**	**297**	**269**	**259**	**239**	**237**	**198**	**199**	**187**

Units: kilotonnes

[1] "Other" for carbon monoxide includes emissions from Solvent Processes, Agriculture, Waste as well as 1A5b, 7A.

Figure 2-15 Scotland Carbon Monoxide Emissions by Sector, 1990-2011



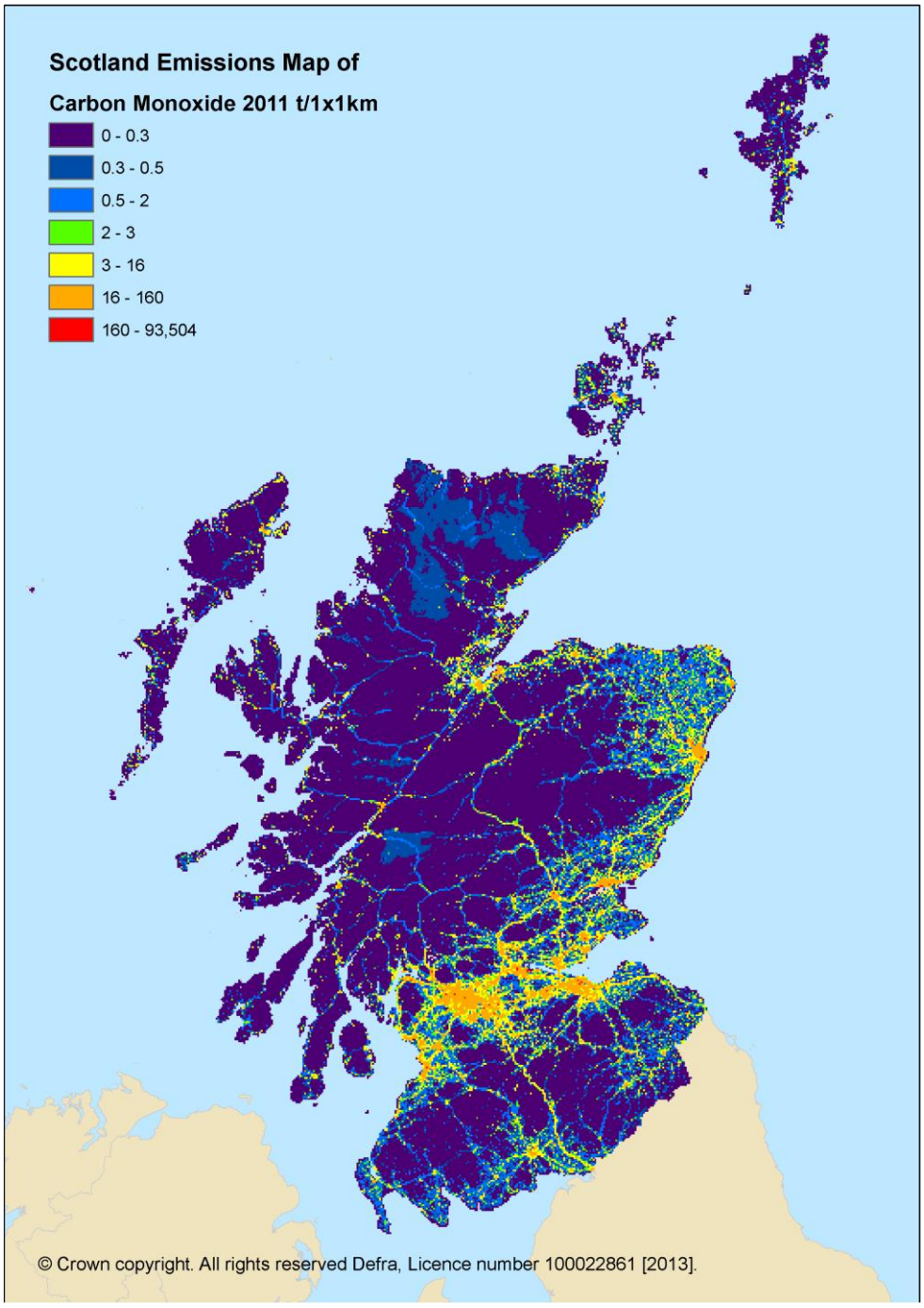
Carbon monoxide emissions in Scotland have declined by 79% since 1990 and account for 9% of the UK total. In 2011, 28% of CO emissions in Scotland stem from road transport combustion sources (down by 90% since 1990), whilst 20% stem from industrial combustion (up 10% since 1990) and 37% from commercial, domestic

and agricultural combustion (down 64% since 1990). The increase in industrial emissions is driven in recent years by an upturn in biomass use for industrial combustion, which has increased four-fold in Scotland since 2008.

Between 2010 and 2011, Scottish carbon monoxide emissions fell by 6%, driven predominantly by the reduction in emissions from road transport (down 18%) and reductions in emissions from power stations (down 19%), partly offset by the increase in industrial emissions (up 12%) due to higher emissions from biomass fuel use.

Between 2008 and 2009, emissions fell sharply by 16%, driven predominantly by the reduction in emissions from road transport, with further reductions in emissions from industrial combustion emissions driven by the economic downturn.

Figure 2-16 Map of Carbon Monoxide Emissions in Scotland, 2011



2.2.3 Wales Carbon Monoxide Inventory by Sector, 1990-2011

The table and graph below give a summary of the carbon monoxide emissions in Wales by broad NFR sector categories. The disaggregation of these categories is available in Appendix A (see Sector Category column).

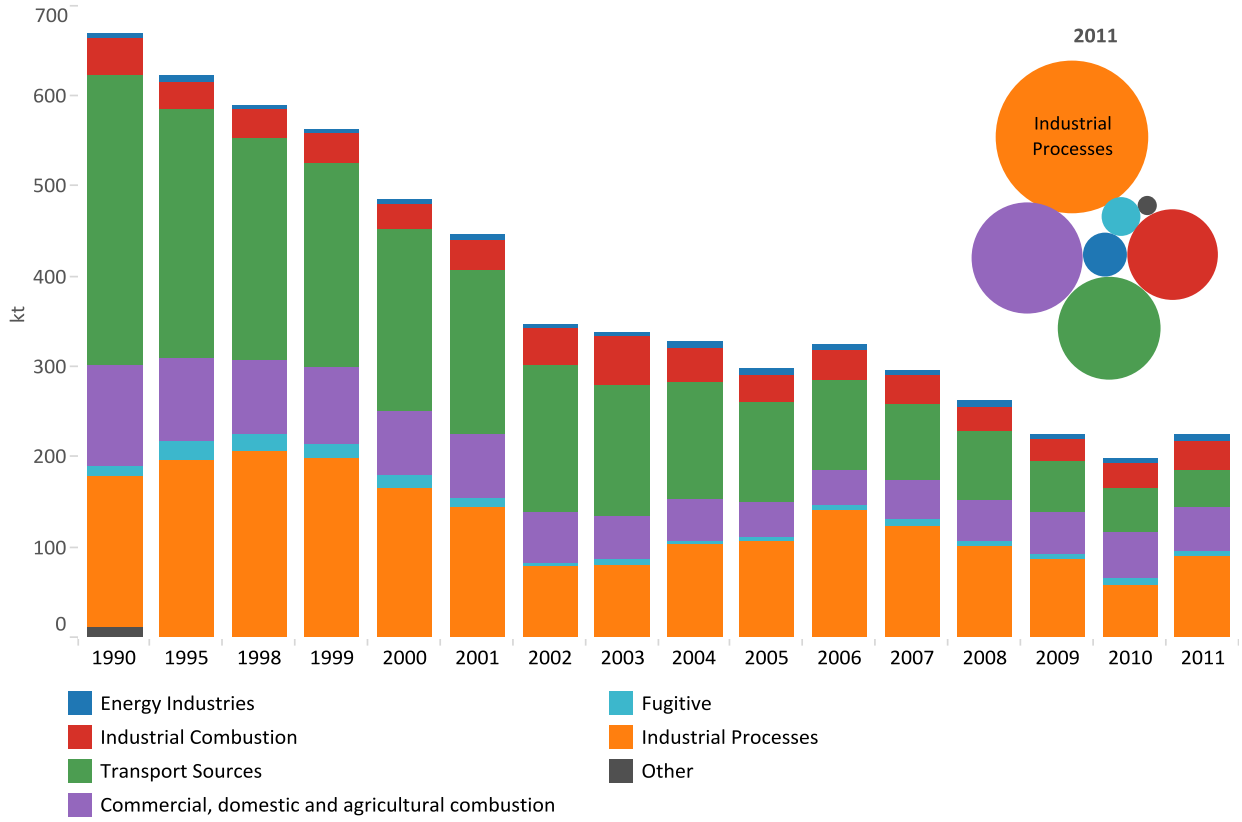
Table 2-11 Wales Emissions of Carbon Monoxide by Sector, 1990-2011

	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Energy Industries	6.3	6.2	4.4	3.9	5.2	5.9	4.9	5.2	6.8	6.0	6.6	5.2	6.8	5.9	6.8	7.5
Industrial Combustion	41.0	29.8	31.1	32.6	29.0	33.6	41.3	53.1	38.3	30.2	33.4	31.6	26.9	23.4	27.9	31.8
Transport Sources	321.1	276.2	245.6	226.2	200.8	181.0	162.3	144.3	128.5	111.5	98.9	84.4	75.7	57.0	49.1	40.9
Commercial, domestic and agricultural combustion	110.0	91.0	80.9	84.2	69.5	70.6	55.1	48.3	46.2	37.4	37.9	42.1	45.0	44.8	49.0	47.8
Fugitive	12.3	19.0	19.0	14.8	15.2	8.5	3.5	4.9	3.4	3.0	6.5	7.0	5.1	5.1	6.2	5.8
Industrial Processes	165.8	197.8	206.9	198.7	164.6	143.6	78.6	81.0	103.4	107.6	140.3	124.0	101.1	87.5	58.8	90.1
Other [1]	13.3	1.7	1.6	1.6	1.6	2.7	1.6	1.6	1.6	1.5	1.6	1.6	1.5	1.5	1.4	1.4
Total	**670**	**622**	**590**	**562**	**486**	**446**	**347**	**338**	**328**	**297**	**325**	**296**	**262**	**225**	**199**	**225**

Units: kilotonnes

[1] "Other" for carbon monoxide includes emissions from Solvent Processes, Agriculture, Waste as well as 1A5b, 7A.

Figure 2-17 Wales Carbon Monoxide Emissions by Sector, 1990-2011

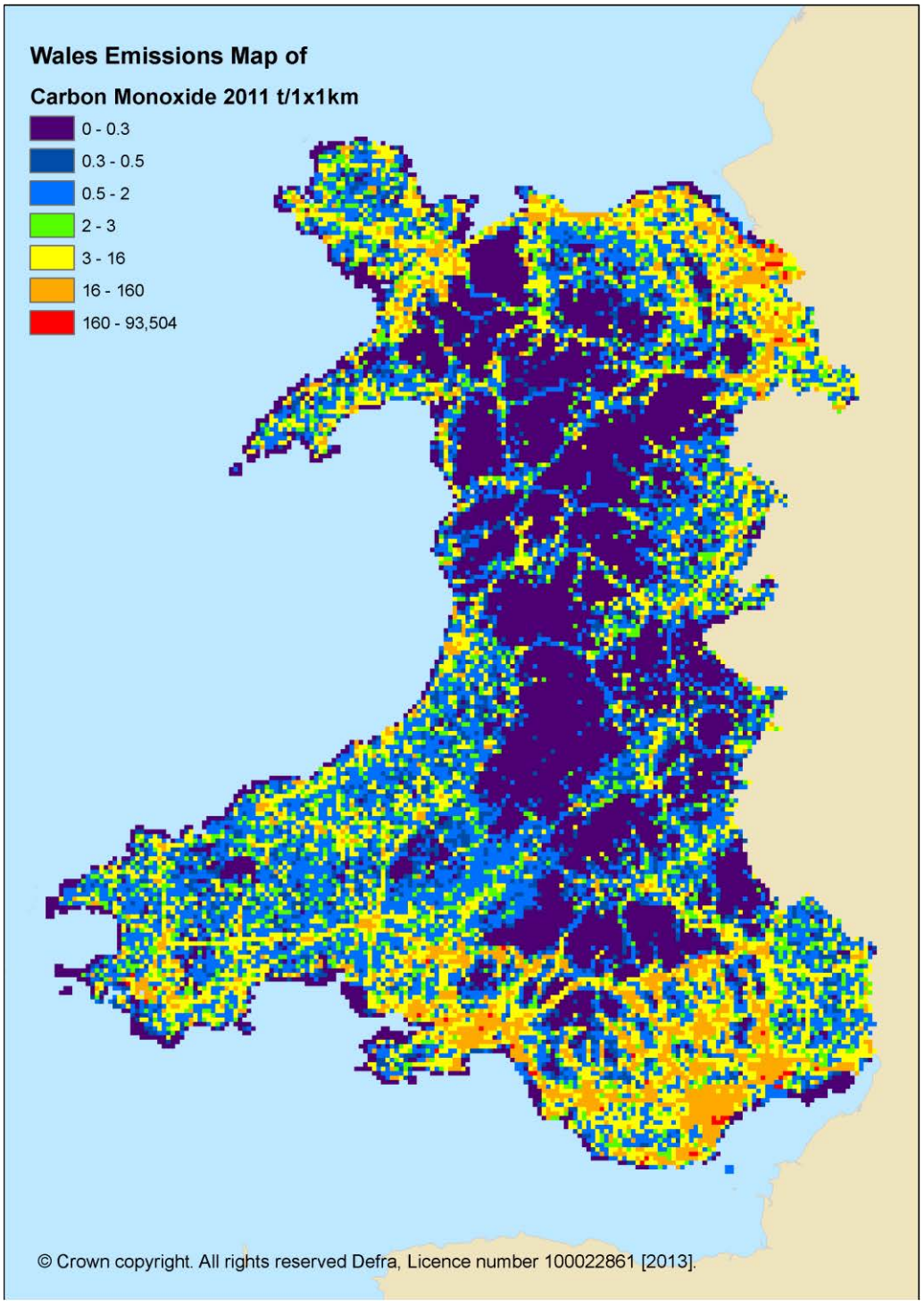


Carbon monoxide in Wales emissions have declined by 66% since 1990 and account for 11% of the UK total. The iron and steel industry contributes significantly to the Welsh total, with a total of 42%. Emissions from iron

and steel production have decreased across the time series (down by 66% since 1990) with the exception of annual increases in 2006 and 2011 (9% and 13% respectively) driven by trends in iron and steel production output. In 2011, 17% of CO emissions in Wales stem from road transport combustion sources (down by 88% since 1990), whilst 21% stem from commercial, domestic and agricultural combustion (down 57% since 1990).

On a per capita basis, Welsh emissions are higher than the UK average, due to the large contribution of emissions from iron and steel production. The continuing contribution of emissions from this source has also meant that the percentage decline in emissions per capita in Wales is lower than the other DAs (-69%, compared with a UK-wide decline of 79-80%).

Figure 2-18 Map of Carbon Monoxide Emissions in Wales, 2011



2.2.4 Northern Ireland Carbon Monoxide Inventory by Sector, 1990-2011

The table and graph below give a summary of the carbon monoxide emissions in Northern Ireland by broad NFR sector categories. The disaggregation of these categories is available in Appendix A (see Sector Category column).

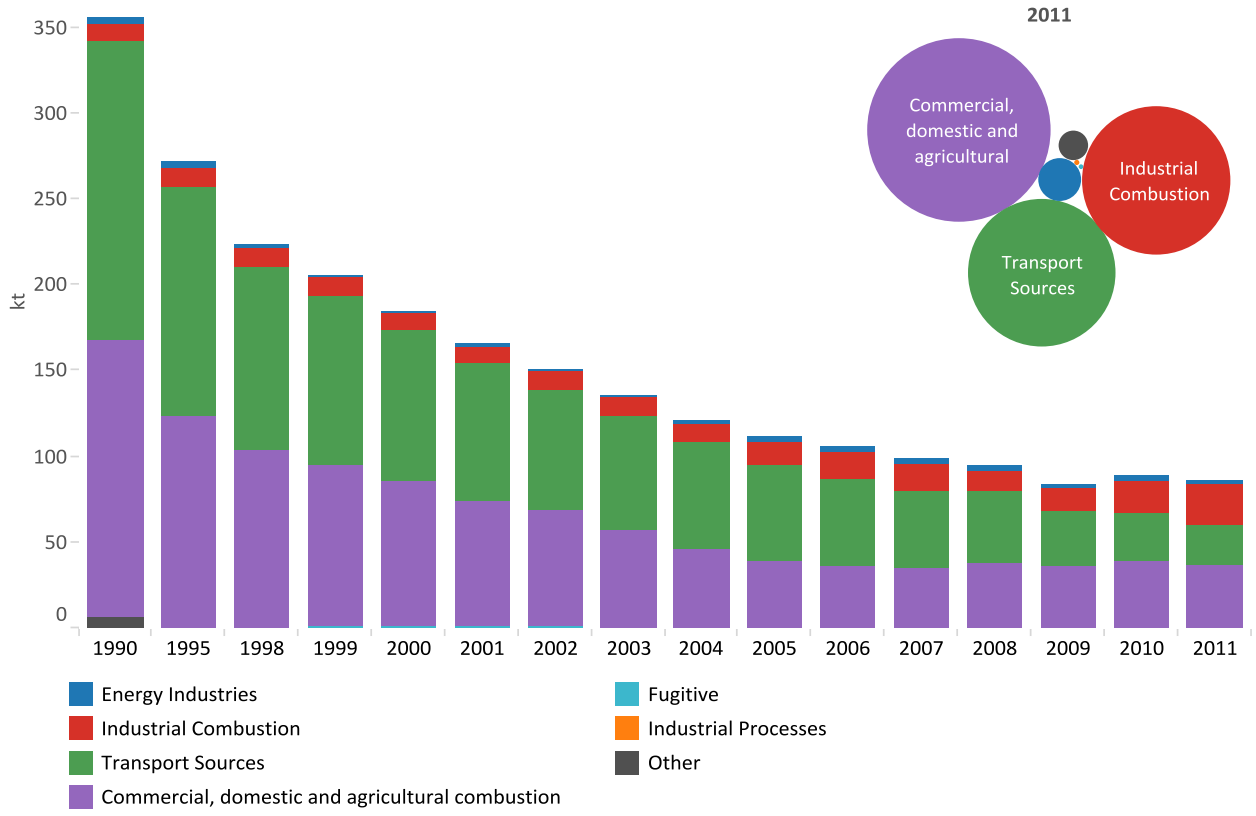
Table 2-12 Northern Ireland Carbon Monoxide Emissions by Sector, 1990-2011

	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Energy Industries	4.1	3.8	2.1	1.3	1.3	1.4	1.1	1.1	2.0	3.3	2.8	2.6	2.7	2.5	2.1	2.0
Industrial Combustion	10.1	11.2	10.6	10.8	9.8	9.3	10.5	11.2	9.8	13.1	15.4	16.0	12.0	13.5	19.0	23.5
Transport Sources	174.3	133.2	106.5	98.7	87.9	80.4	70.6	66.1	62.4	56.6	51.0	45.5	42.8	32.0	27.8	23.2
Commercial, domestic and agricultural combustion	160.3	122.4	102.5	93.3	84.5	72.8	66.9	56.1	45.0	37.4	34.8	33.4	36.3	35.0	38.4	35.9
Fugitive	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Industrial Processes	0.2	0.2	0.2	0.4	0.4	0.4	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other [1]	6.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.9
Total	**356**	**272**	**223**	**206**	**185**	**165**	**151**	**136**	**120**	**111**	**105**	**99**	**95**	**84**	**88**	**86**

Units: kilotonnes

[1] "Other" for carbon monoxide includes emissions from Solvent Processes, Agriculture, Waste as well as 1A5b, 7A.

Figure 2-19 Northern Ireland Carbon Monoxide Emissions by Sector, 1990-2011

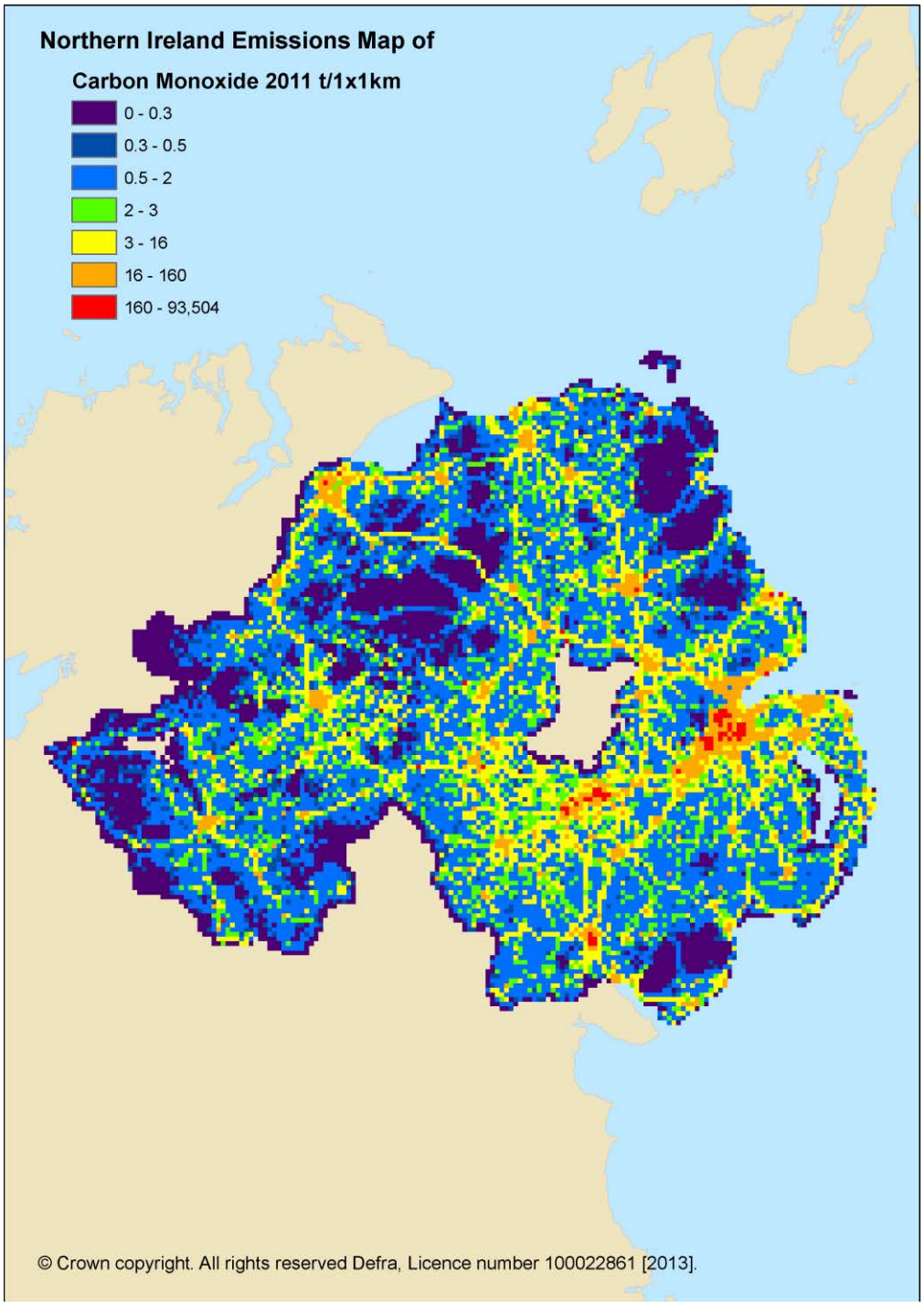


Carbon monoxide emissions in Northern Ireland have declined by 76% since 1990 and accounted for 4% of the UK total in 2011. 25% of CO emissions in Northern Ireland stem from road transport combustion sources

(down by 88% since 1990). In 2011, 42% of the Northern Ireland total emission comes from commercial, agricultural and residential combustion (down 78% since 1990), which is a much higher contribution than in other DAs (contributing 19%, 37% and 21% within England, Scotland and Wales, respectively) due to the greater use of solid fuels as a result of the less well developed gas network in Northern Ireland.

Between 2010 and 2011, emissions fell by 3%, driven by reductions in emissions from passenger cars and from the residential sector where lower emissions from solid fuels and oils are estimated in 2011. An increase in emissions is evident in the industrial sector between 2010 and 2011, partly offsetting the reductions in other sectors; this increase is due to higher biomass fuel use in the industrial sector in 2011, which shows in increasing trend in recent years, up three-fold since 2005.

Figure 2-20 Map of Carbon Monoxide Emissions in Northern Ireland, 2011

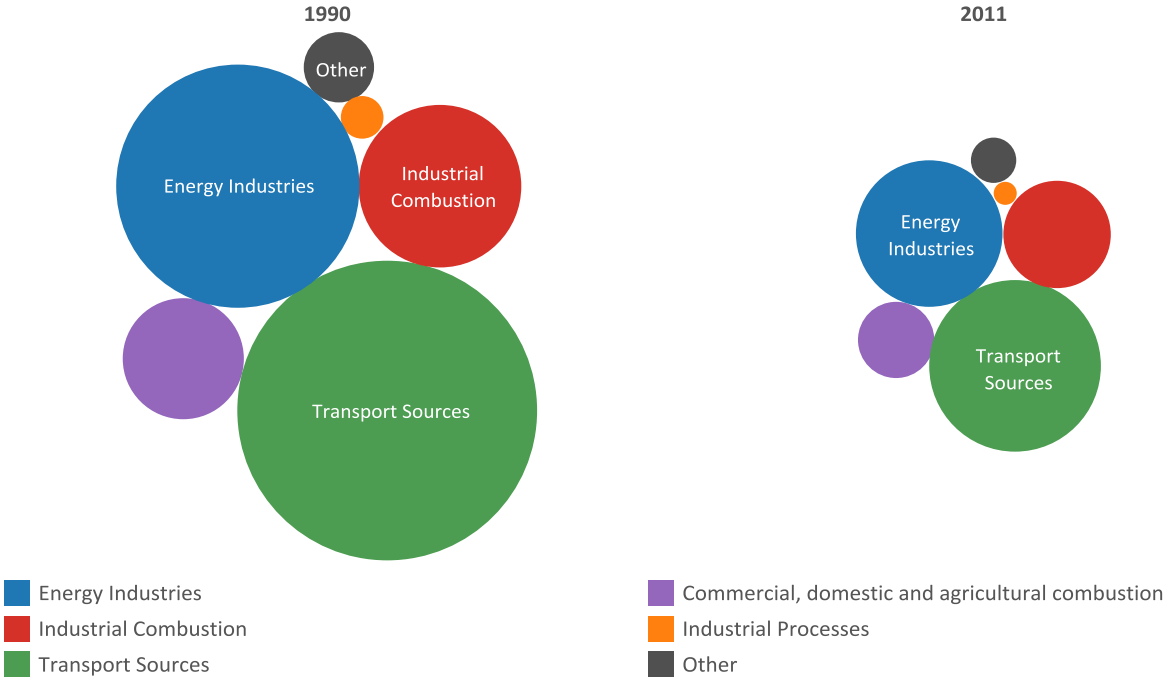


2.3 NITROGEN OXIDE

Across the UK, emissions of oxides of nitrogen (NO_x) arise primarily from combustion sources. The estimation of these emissions is complex since the nitrogen can be derived from either the fuel or atmospheric nitrogen. The emission is dependent on the conditions of combustion, in particular temperature and excess air ratio, which can vary considerably. Thus combustion conditions, load and even state of maintenance are important.

UK emission estimates for nitrogen oxides are presented below for 1990 and 2011 (**Figure 2-21**Figure 2-11). UK emissions have decreased by 64% between 1990 and 2011 in 2011 as indicated by the change in area between the 1990 and 2011 graph.

Figure 2-21 UK Nitrogen Oxides Emissions by Sector (1990 and 2011)



The main three combustion sources of NO_X are:

- **Transport sources** – in 2011 road vehicles contributed 33% of total UK NO_X emissions. Since 1990 there has been a steady decline in emissions due to the introduction of catalytic converters on cars and stricter regulations on truck emissions. Between 2008 and 2009, there was an 18% reduction in the emissions from passenger cars which was mainly driven by improvement in catalyst repair rates[6]. This was due to the introduction of the Regulations Controlling Sale and Installation of Replacement Catalytic Converters and Particle Filters for Light Vehicles for Euro 3 (or above) LDVs after June 2009. However, roadside measurements of ambient NO_X concentrations and a recent study undertaken by King's College London and AEA (now Ricardo-AEA) (Carslaw *et al.*, 2011) have indicated that the trend of ambient NO_X concentration has been fairly flat since 2002, and there is also some evidence

[6] A sensitive parameter in the emission calculations for petrol cars is the assumption made about the proportion of the fleet with catalyst systems that have failed, for example due to mechanical damage or failure of the lambda sensor. Following discussions with DfT, it is assumed that the failure rate is 5% per annum for all Euro standards, and that up to 2008 only 20% of failed catalysts were rectified properly, but those that were rectified were done so within a year of failing. The revisions are based on evidence on fitting of replacement catalysts. According to DfT there is evidence that a high proportion of replacement catalysts were not Type Approved and do not restore the emission performance of the vehicle to its original level (DfT 2009). This is being addressed through the Regulations Controlling Sale and Installation of Replacement Catalytic Converters and Particle Filters for Light Vehicles for Euro 3 (or above) LDVs after June 2009. Therefore a change in the repair rate is taken into account for Euro 3 and above petrol LDVs from mid-2009, assuming all failed vehicles are rectified properly.

from roadside remote sensing of exhaust plumes from a large number of vehicles indicating that NO_X emissions are significantly higher than indicated by the current emissions factors. Consideration is therefore currently underway by Defra and the inventory team to update the NO_X emission factors for the next inventory cycle so that they are more representative of the real world observations and the latest evidence on vehicle emissions. Research indicates that conurbations and city centres show high localised emissions due to the combination of road transport, domestic and commercial combustion sources. Similarly, around airports, ports and major terminals, significant localised emissions arise from aviation, shipping, railway locomotives and road vehicles.

- **Power generation** (part of Energy Industries) – since 1988 the electricity generators have adopted a programme of progressively fitting low-NO_X burners to their 500 MWe (megawatt electric) or larger coal fired units. More recently the increased use of nuclear generation and the introduction of CCGT (Combined Cycle Gas Turbine) plant burning natural gas have further reduced NO_X emissions. The emissions from the low-NO_X turbines used are much lower than those of pulverised coal fired plant even when low-NO_X burners are fitted. Assuming that these trends continue, power station emissions are expected to fall further. An additional factor has been the recent retrofitting of Boosted Over Fire Air (BOFA) systems to reduce NO_X formation and ensure compliance with the Large Combustion Plant Directive. Power station NO_X emissions peaked in 2006 but in recent years have shown a decreasing trend driven by reductions in emissions from coal burning power stations due to the use of BOFA. In 2011, power station NO_X emissions are 42% lower than the 2006 peak.

- **Industrial combustion** – emissions from industrial combustion have declined by 56% since 1990 and they currently contribute 16% to total UK emissions. This is primarily due to the decline in coal use in favour of gas and electricity.

Emissions of nitrogen oxides for England, Wales, Scotland and Northern Ireland are summarised in the tables and graphs below. **Figure 2-22** shows the split of emissions between the four Devolved Administrations for the entire time series with

Table 2-13 presenting this split as a percentage for 1990 and 2011. **Table 2-14** shows per capita emissions for 1990 and 2011.

Figure 2-22 UK Nitrogen Oxides Emissions by Devolved Administration, 1990-2011

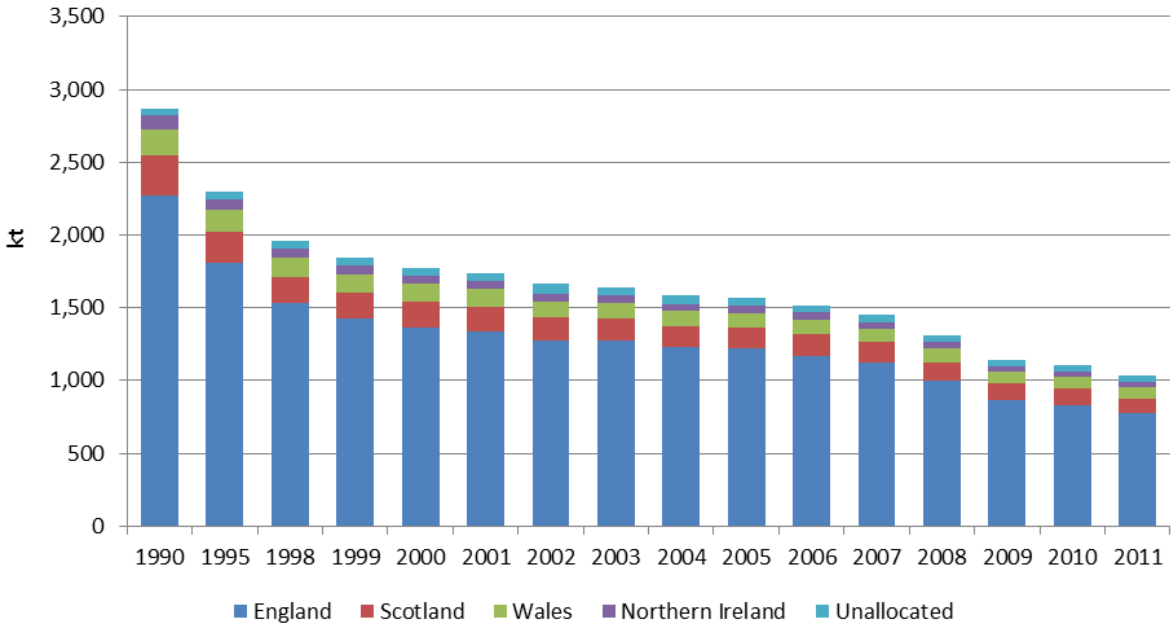


Table 2-13 Proportion of UK Nitrogen Oxides Emissions by Devolved Administration

Year	England	Scotland	Wales	Northern Ireland	Unallocated
1990	79%	10%	6%	3%	2%
2011	75%	10%	8%	3%	4%

Table 2-14 Emissions of NO_x per capita by Devolved Administration (kg/head)

Year	England	Scotland	Wales	Northern Ireland	UK
1990	47.6	55.5	61.3	60.7	50.1
2011	14.6	18.7	25.3	17.6	16.3

2.3.1 England Nitrogen Oxides Inventory by Sector, 1990-2011

The table and graph below give a summary of the NO_X emissions in England by broad NFR sector categories. The disaggregation of these categories is available in Appendix A (see Sector Category column).

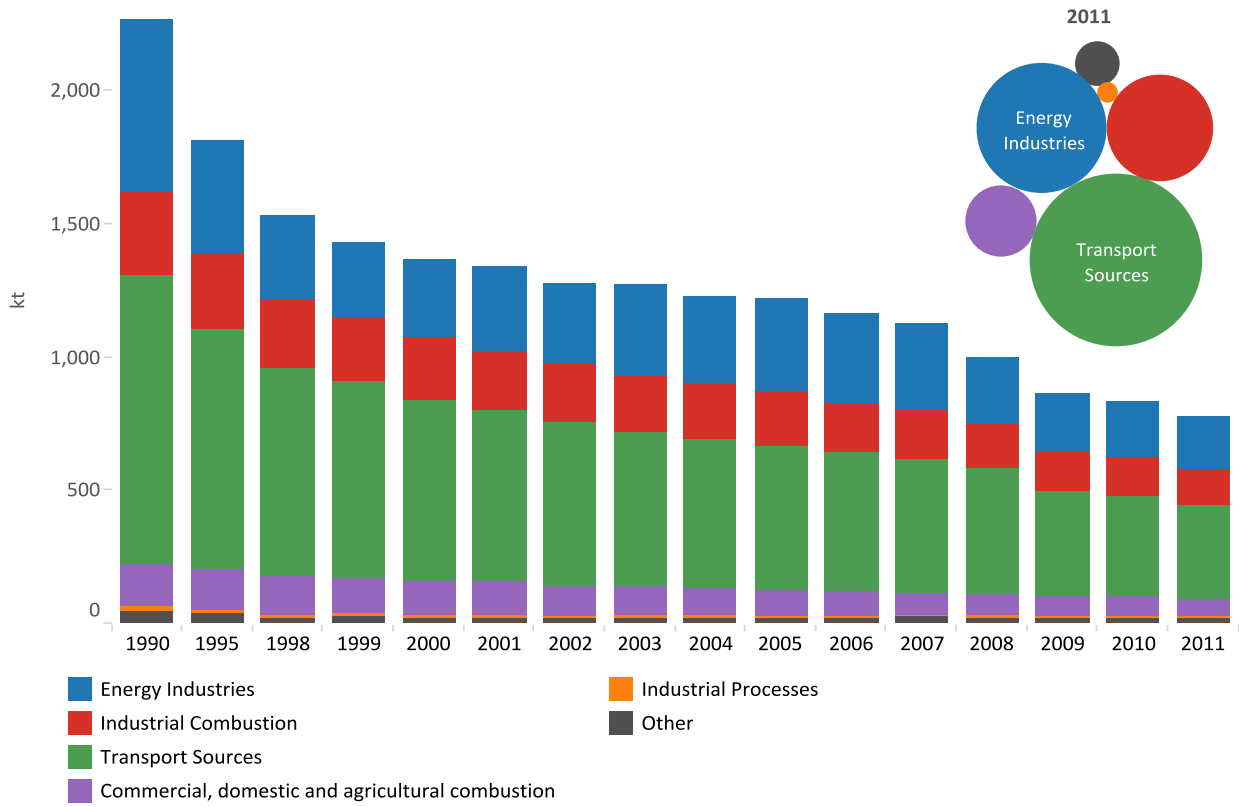
Table 2-15 England Emissions of Nitrogen Oxides by sector, 1990-2011

	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Energy Industries	651	417	315	280	294	314	310	344	327	346	336	325	244	227	208	201
Industrial Combustion	310	288	258	244	234	224	215	211	206	206	189	188	170	140	145	135
Transport sources	1,085	902	780	732	675	643	612	579	560	540	521	500	471	397	376	354
Commercial, domestic and agricultural combustion	156	144	137	132	124	120	109	103	97	92	84	78	76	69	72	60
Industrial Processes	17	13	12	13	11	11	8	9	9	8	8	8	8	6	5	5
Other [1]	49	43	27	28	27	26	25	26	27	25	26	29	27	25	26	24
Total	**2,268**	**1,807**	**1,528**	**1,429**	**1,364**	**1,338**	**1,279**	**1,273**	**1,226**	**1,217**	**1,164**	**1,127**	**995**	**866**	**831**	**778**

Units: kilotonnes

[1] "Other" for nitrogen oxides includes emissions from Fugitive, Solvent Processes, Agriculture, Waste as well as 1A5b, 7A.

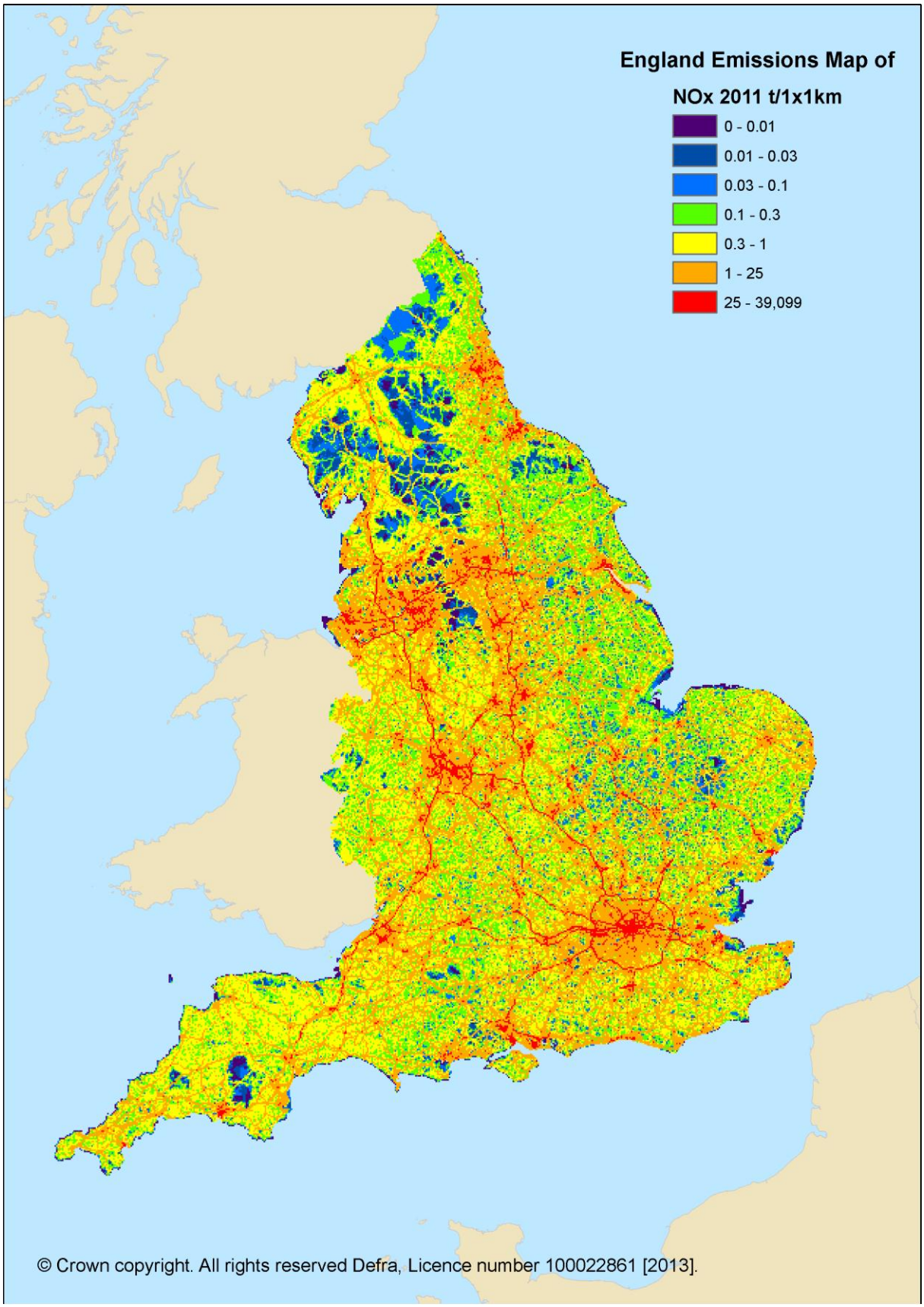
Figure 2-23 England Nitrogen Oxides Emissions by Sector, 1990-2011



Nitrogen oxides emissions in England have declined by 66% since 1990 and account for 75% of the UK total. Power generation is a very significant source, accounting for 23% of the England total in 2011, although emissions from this source have reduced by 71% since 1990. In 2011, 36% of NO_X emissions in England stemmed from road transport combustion sources (down by 73% since 1990), whilst 17% stemmed from industrial combustion (down 57% since 1990). Notable increases in emissions arise from railways (up by 92%

since 1990 but accounting for only 4% of England's 2011 total emission) and from international aviation landing and take-off (up by 104% since 1990 and only accounting for 1% of total emissions in 2011).

Figure 2-24 Map of Nitrogen Oxides Emissions in England, 2011



2.3.2 Scotland Nitrogen Oxides Inventory by Sector, 1990-2011

The table and graph below give a summary of the NO_X emissions in Scotland by broad NFR sector categories. The disaggregation of these categories is available in Appendix A (see Sector Category column).

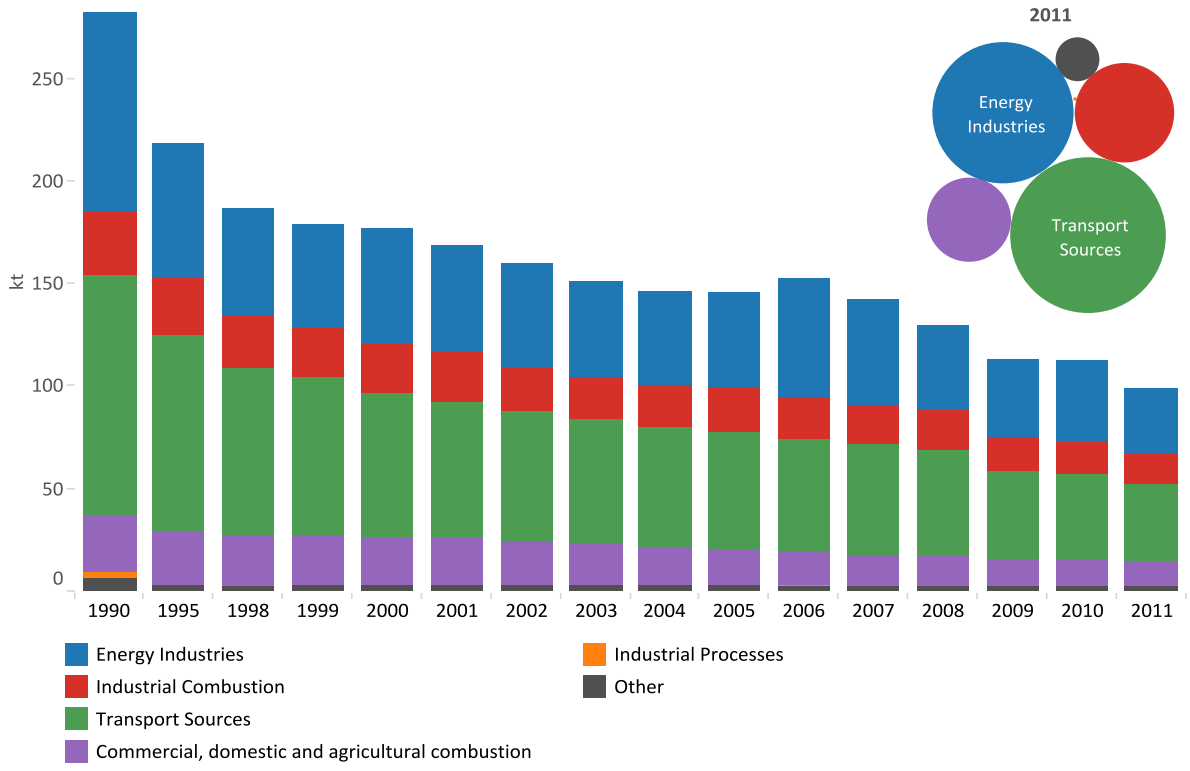
Table 2-16 Scotland Emissions of Nitrogen Oxides by sector, 1990-2011

	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Energy Industries	97.0	65.7	52.2	50.1	56.3	51.7	50.2	47.3	46.0	45.7	58.0	51.0	41.1	37.7	39.2	31.1
Industrial Combustion	31.3	27.5	25.3	24.3	24.3	24.3	21.4	20.3	20.4	21.5	19.9	19.3	19.8	16.3	16.0	15.4
Transport sources	117.1	95.5	80.9	76.3	70.0	66.2	63.7	60.6	58.6	57.0	55.5	54.1	51.2	43.1	40.8	37.8
Commercial, domestic and agricultural combustion	26.8	25.4	24.7	24.0	22.6	22.2	20.4	19.3	17.8	17.1	15.5	14.2	13.9	12.7	12.9	11.0
Industrial Processes	2.91	0.16	0.09	0.08	0.07	0.07	0.06	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02
Other [1]	7.1	3.9	3.2	3.8	3.7	3.9	3.6	3.7	3.6	3.6	3.5	3.4	3.3	2.9	2.9	3.0
Total	**282**	**218**	**186**	**179**	**177**	**168**	**159**	**151**	**146**	**145**	**152**	**142**	**129**	**113**	**112**	**98**

Units: kilotonnes

[1] "Other" for nitrogen oxides includes emissions from Fugitive, Industrial Processes, Solvent Processes, Agriculture, Waste as well as 1A5b, 7A.

Figure 2-25 Scotland Nitrogen Oxides Emissions by Sector, 1990-2011

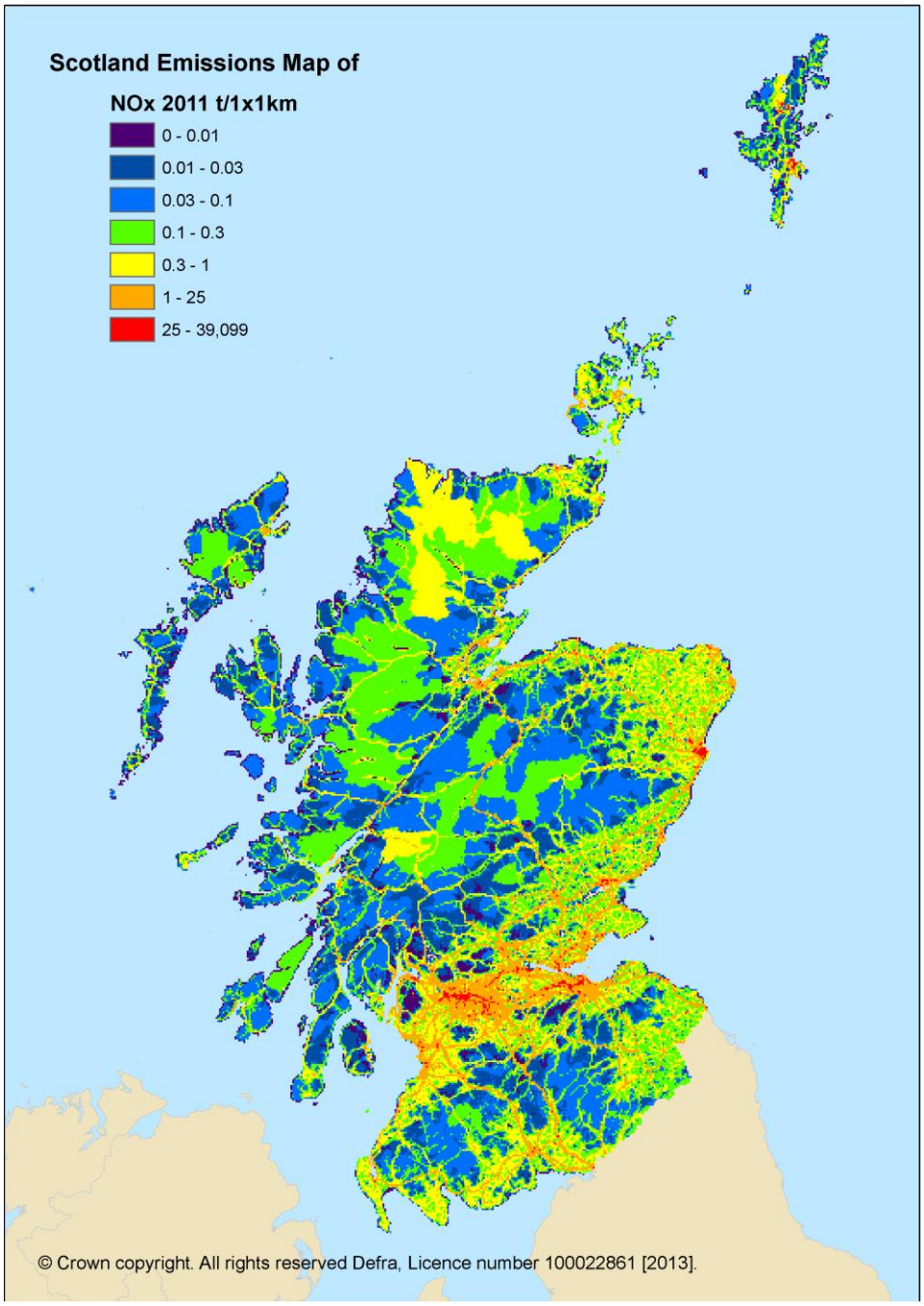


Nitrogen oxides emissions in Scotland have declined by 65% since 1990 and currently account for 10% of the UK total. Power generation (accounted for within "Energy Industries") is a significant source of NO_X emissions, accounting for 25% of the Scotland total in 2011 although emissions from this source have reduced by 71% since 1990.

Recent trends in electricity generation have dominated the overall trends in the inventory. Following a peak in coal-fired generation in 2006, power station NOX emissions from coal-fired stations have declined by 56% due to a combination of abatement and reduced generation from coal. Over the same period, NOX emissions from gas-fired power stations have declined by 34%, reflecting a decline in gas-fired electricity generation since 2006.

A further 29% of NO_X emissions in Scotland arise from road transport sources (down by 73% since 1990), 16% stemmed from industrial combustion (down 51% since 1990) and 5% is from agricultural mobile machinery (down 65% since 1990). Increases in emissions are apparent mostly in relatively minor source sectors such as international aviation landing and take-off (LTO) (1A3ai(i): up by 141% since 1990). The most significant increase can be seen in the railway sector where emissions have increased by 45% since 1990 and account for 3% of total emissions in 2011. This change is due to increases in fuel oil consumption by the rail sector from 1990 due to rise in passenger train km and freight train km during this time.

Figure 2-26 Map of Nitrogen Oxides Emissions in Scotland, 2011



2.3.3 Wales Nitrogen Oxides Inventory by Sector, 1990-2011

The table and graph below give a summary of the NO_X emissions in Wales by broad NFR sector categories. The disaggregation of these categories is available in Appendix A (see Sector Category column).

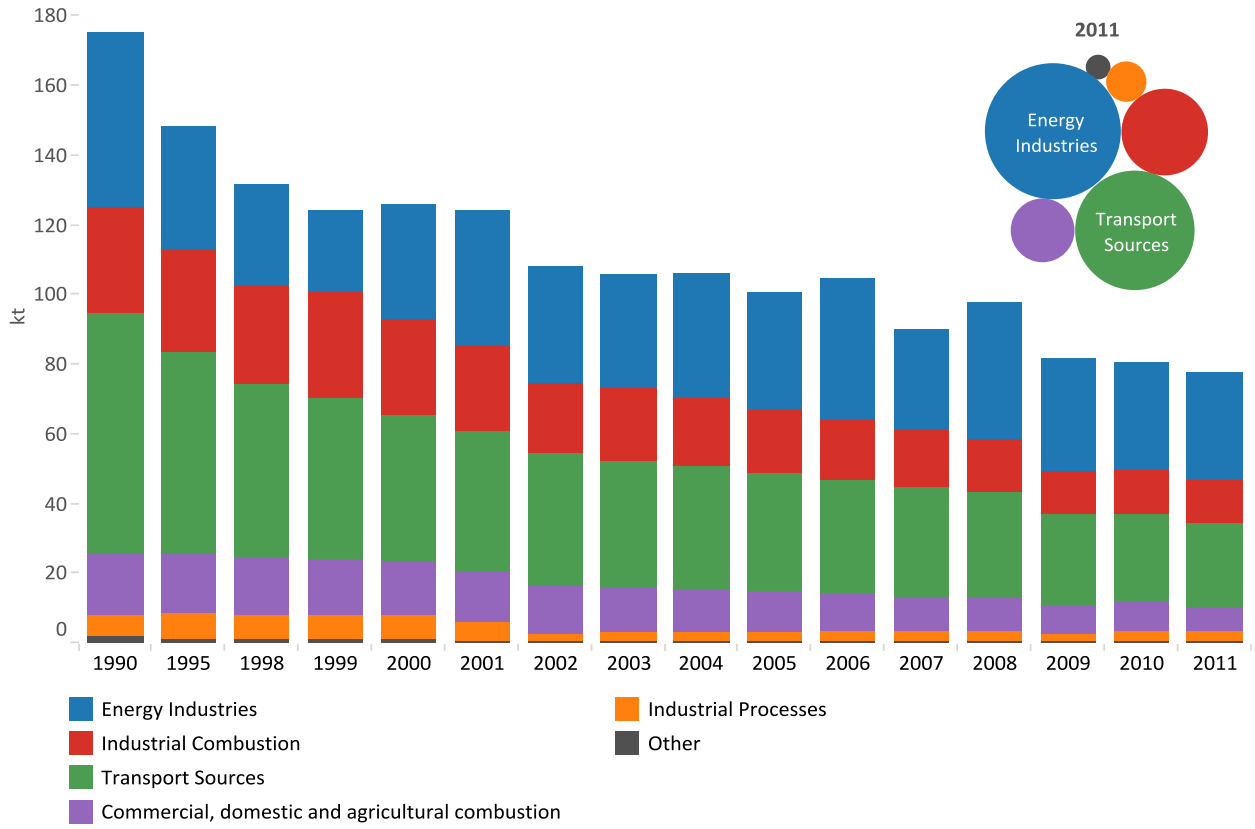
Table 2-17 Wales Emissions of Nitrogen Oxides by sector, 1990-2011

	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Energy Industries	50.0	35.4	28.8	23.5	32.6	38.9	33.0	32.7	35.8	33.7	40.7	28.3	39.2	32.5	30.6	30.8
Industrial Combustion	30.5	29.5	28.4	30.5	27.4	24.6	20.1	20.8	19.6	18.2	17.1	16.6	15.3	12.2	13.0	12.5
Transport sources	69.4	58.2	49.8	46.3	42.5	40.2	38.5	36.4	35.4	33.9	32.7	31.7	30.4	26.2	25.0	23.8
Commercial, domestic and agricultural combustion	17.3	16.7	16.0	15.6	14.7	14.3	13.2	12.6	11.8	11.0	9.9	9.0	8.6	7.9	8.0	6.8
Industrial Processes	5.72	7.10	7.10	7.25	7.01	5.14	1.83	2.11	2.47	2.53	2.97	2.86	2.81	1.93	2.61	2.71
Other [1]	2.3	1.6	1.2	1.2	1.2	1.2	1.1	1.1	1.1	1.0	1.1	1.2	1.1	1.0	1.1	1.0
Total	**175**	**148**	**131**	**124**	**125**	**124**	**108**	**106**	**106**	**100**	**105**	**90**	**97**	**82**	**80**	**78**

Units: kilotonnes

[1] "Other" for nitrogen oxides includes emissions from Fugitive, Solvent Processes, Agriculture, Waste as well as 1A5b, 7A.

Figure 2-27 Wales Nitrogen Oxides Emissions by Sector, 1990-2011



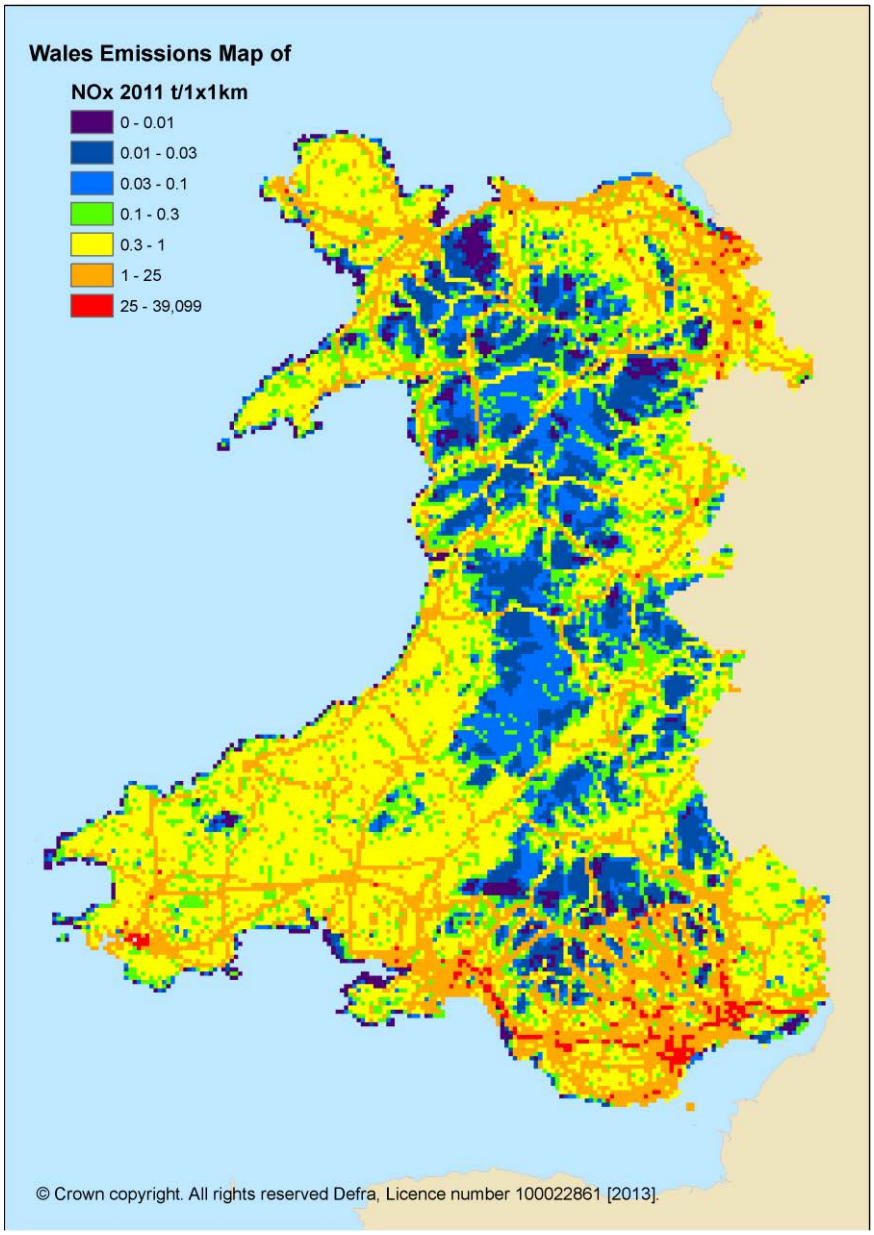
Nitrogen oxides emissions in Wales have declined by 56% since 1990 and accounted for 8% of the UK total in 2011. Power generation accounted for 30% of the Wales NO_X inventory total in 2011; emissions from this source have reduced by 45% since 1990. Recent trends in electricity generation have dominated the overall trends in the Wales NO_X inventory, with large fluctuations in coal-fired generation in particular (due to a plant shut-down at Aberthaw during 2007 to retro-fit 2 units with Flue Gas Desulphurisation abatement). Between

2007 and 2008, coal-fired generation increased by nearly 83% (up to 9,364 GWh) once Aberthaw came back on-line, then decreasing between 2008 and 2009 by 30% (down to 6,547 GWh).

Coal-fired generation in 2010 and 2011 has been driven by electricity demand and fuel prices, with a reduction between 2009 and 2010 and then a 4% increase between 2010 and 2011, reflecting a UK-wide shift from gas-fired generation to coal-fired generation due to high gas prices in 2011. Gas-fired generation decreased by 35% between 2010 and 2011 to 9,880 GWh due the high gas prices and this led to a large reduction in emissions. Overall power sector emissions are down by 2.5% between 2010 and 2011 as a result of the decline in emissions from gas use.

A further 23% of NO_X emissions in Wales stem from road transport combustion sources (down by 72% since 1990), 16% stem from industrial combustion (down 59% since 1990) and 6% of emissions are from petroleum refining (down 16% since 1990). Notable increases in emissions arise from railways (up by 63% since 1990 to 3% of the 2011 Wales total) and from aviation landing and take-off (LTO) (1A3ai(i): up by 100% since 1990 and 1A3aii(i): up by 71% since 1990). Despite these large percentage increases since 1990, aviation emissions remain a small component of the Wales NOx inventory accounting for less than 1% of the emissions in Wales in 2011).

Figure 2-28 Map of Nitrogen Oxides Emissions in Wales, 2011



2.3.4 Northern Ireland Nitrogen Oxides Inventory by Sector, 1990-2011

The table and graph below give a summary of the NO_X emissions in Northern Ireland by broad NFR sector categories. The disaggregation of these categories is available in Appendix A (see Sector Category column).

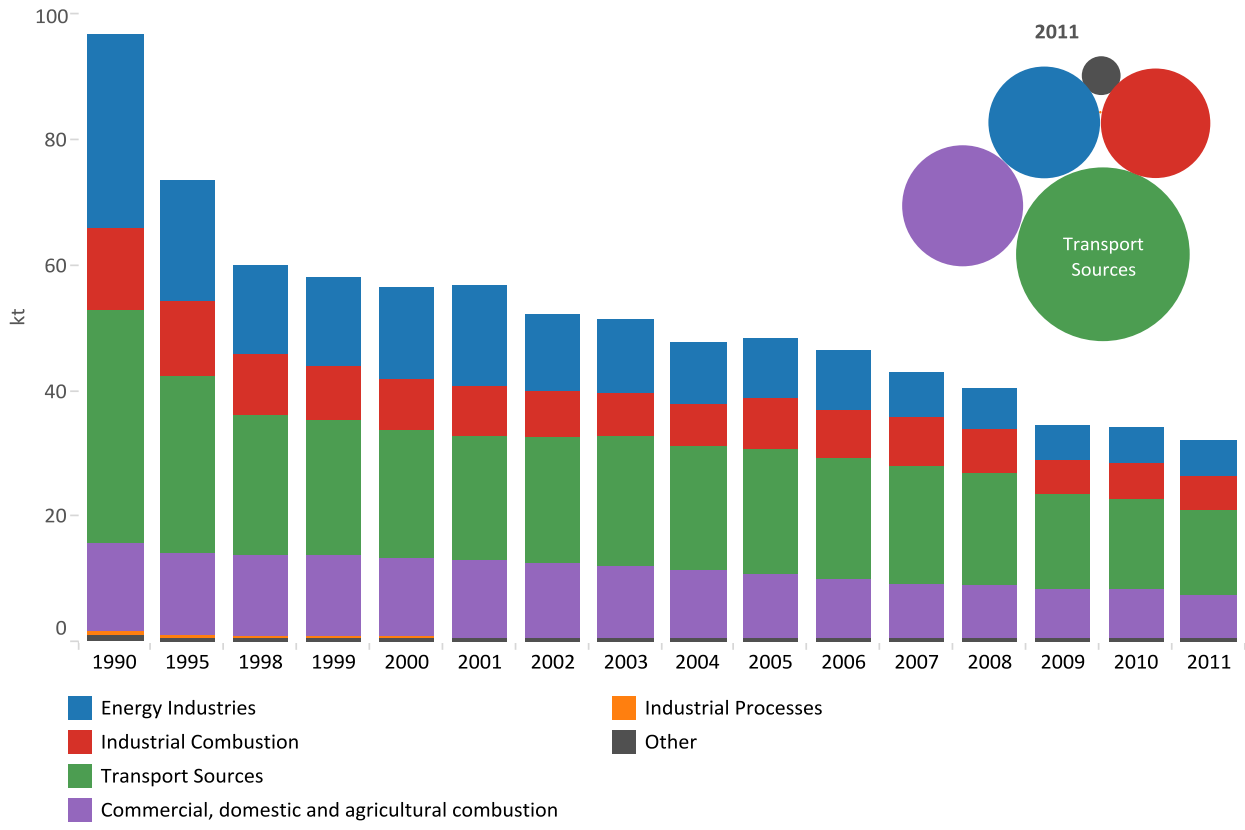
Table 2-18 Northern Ireland Emissions of Nitrogen Oxides by sector, 1990-2011

	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Energy Industries	31.0	19.3	13.9	14.2	14.8	16.0	12.3	11.5	9.8	9.6	9.6	7.0	6.4	5.5	5.7	5.6
Industrial Combustion	12.9	11.8	9.8	8.8	8.1	7.9	7.1	6.7	6.7	8.1	7.5	7.9	7.2	5.4	5.7	5.4
Transport sources	37.3	28.1	22.2	21.3	20.3	19.9	20.2	20.9	20.0	19.7	19.2	18.8	18.0	15.1	14.4	13.6
Commercial, domestic and agricultural combustion	13.7	13.0	12.9	12.8	12.3	12.1	11.7	11.3	10.5	10.1	9.4	8.3	8.0	7.7	7.7	6.6
Industrial Processes	0.72	0.30	0.24	0.25	0.21	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other [1]	1.2	0.9	0.8	0.8	0.8	0.8	0.7	0.8	0.8	0.8	0.8	0.9	0.8	0.7	0.7	0.7
Total	**97**	**73**	**60**	**58**	**57**	**57**	**52**	**51**	**48**	**48**	**47**	**43**	**40**	**34**	**34**	**32**

Units: kilotonnes

[1] "Other" for nitrogen oxides includes emissions from Fugitive, Solvent Processes, Agriculture, Waste as well as 1A5b, 7A.

Figure 2-29 Northern Ireland Nitrogen Oxides Emissions by Sector, 1990-2011

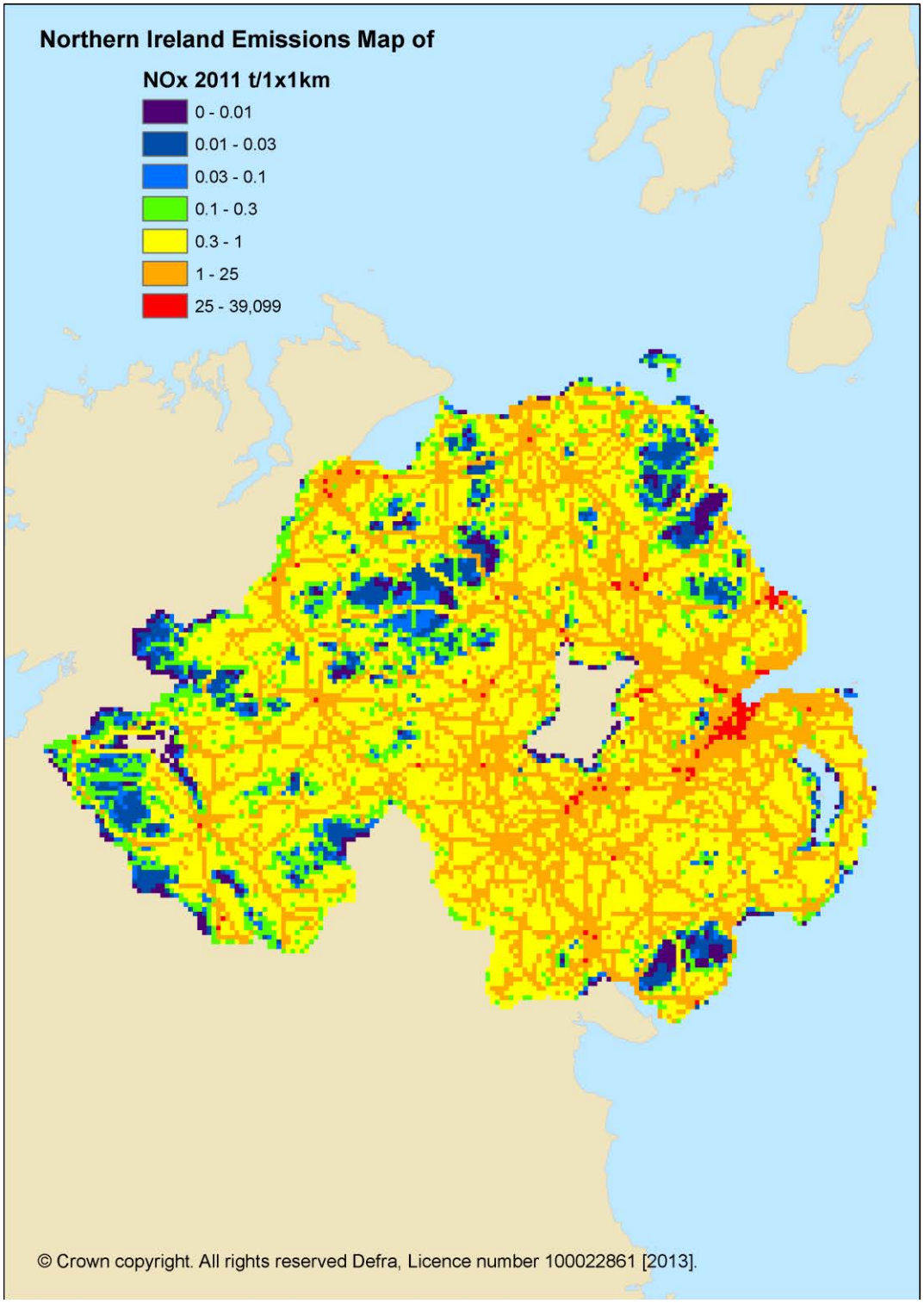


Nitrogen oxides emissions in Northern Ireland have declined by 67% since 1990 and account for only 3% of the UK total. 35% of NO_X emissions in Northern Ireland stem from road transport combustion sources (down by 68% since 1990), whilst 17% stem from industrial combustion (down 58% since 1990). Power generation accounted for 18% of the Northern Irish total in 2011 and emissions from this source have reduced by 82%

since 1990, driven by an 85% reduction in emissions from coal-fired generation as a result of a switch to gas-fired generation and NO_X abatement measures. 9% of emissions from 2011 came from agricultural off road machinery (down 65% since 1990).

Increases in NO_X emissions since 1990 are evident in a handful of minor source sectors including international aviation LTO (up by 271% since 1990), LGV road transport sources (up by 17% since 1990) and from fishing vessels (up 68% since 1990). However, together these sources account for only 3% of the Northern Ireland total emission in 2011.

Figure 2-30 Map of Nitrogen Oxides Emissions in Northern Ireland, 2011

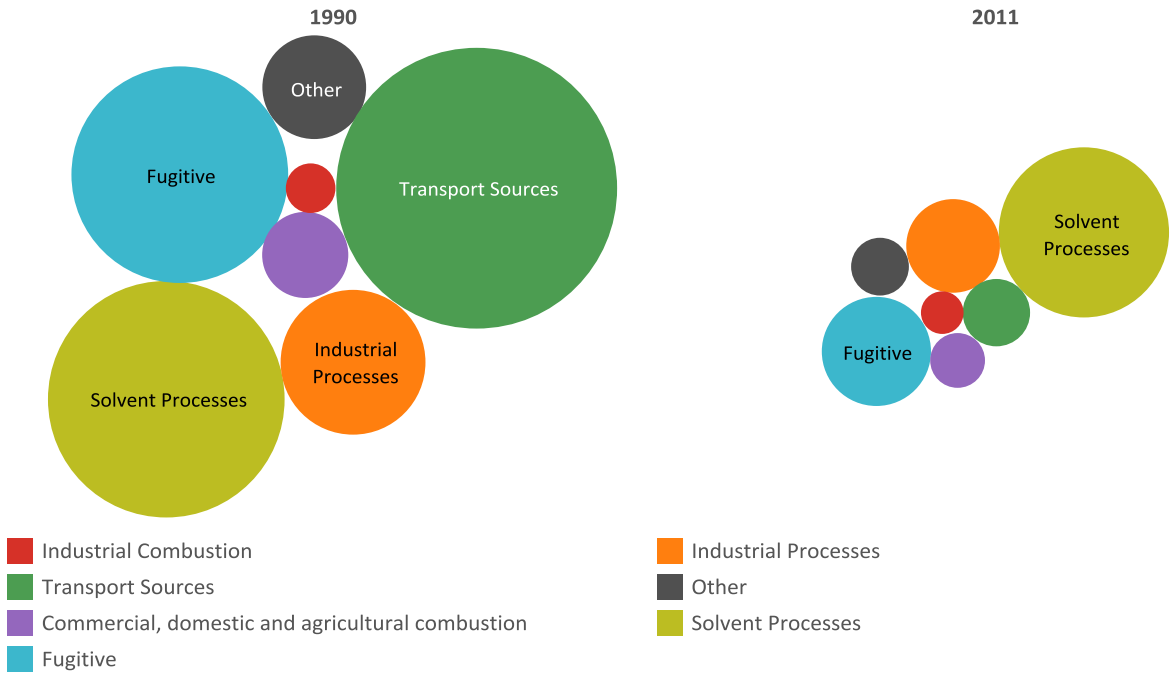


2.4 NON-METHANE VOLATILE ORGANIC COMPOUNDS

Non-Methane Volatile Organic Compounds (NMVOCs) are emitted to air as combustion products, as vapour arising from handling or use of petroleum distillates, solvents or chemicals, and from numerous other sources. The diversity of processes which emit NMVOCs is huge, covering not only many branches of industry, but also transport, agriculture and domestic sources.

UK emission estimates for NMVOCs are presented below for 1990 and 2011 (**Figure 2-31**). UK emissions have decreased by 72% between 1990 and 2011, primarily due to reductions in road transport sources through the use of catalytic converters and fuel switching to diesel technology. This decrease is indicated by the change in area between the 1990 and 2011 graph.

Figure 2-31 UK NMVOC Emissions by Sector (1990 and 2011)



UK emissions inventory data indicate that only 16% of the NMVOC emissions arise from combustion sources (unlike SO_2 and NO_x where the contribution from combustion sources is much higher with 92% and 99% respectively). Of these emissions from combustion sources, it is the transport sector that dominates (70% of combustion emissions). NMVOC emissions are dependent on vehicle speed and are higher on minor and urban major roads than on the high-speed motorways and major roads.

A large proportion of emissions are caused either as a result of the activities of people in and around their homes (e.g. domestic solvent use or domestic combustion), or by widespread industrial activities such as small-scale industrial coating processes, dry cleaners and small bakeries.

- **Solvent and other product use** – this sector comprises industrial and domestic solvent applications (cleaning, degreasing), as well as the manufacturing and processing of chemical products. It represents 46% of the UK total NMVOC emission in 2011. During the 1990s, industrial NMVOC emissions have fallen as a result of emission controls, technological changes, and reduced manufacturing output in some sectors. Emissions from the chemical industry have reduced during the 1990s as tighter emission controls have been introduced. Domestic solvent emissions have also fallen due to a trend towards formulating products such as paints and aerosols with lower solvent contents.

- **Stationary combustion** – this sector includes emissions from public electricity and heat production as well as those from petroleum refining and the manufacture of iron and steel. Emissions from the

petroleum-refineries have fallen significantly due to a reduction in refinery capacity and tighter emission regulations during the 1990s.

- **Production processes** – this sector includes emissions from metal production, road construction, and non-fuel mining. These processes are estimated to comprise 3% of the UK total emission in 2011.

- **Processes in wood, paper pulp and food & drink** – emissions from the food and drink industry comprised approximately 11% of the total NMVOC emission in 2011. The largest source is whisky maturation although bread baking, animal feed manufacture, fat and oil processing and barley malting are also important sources.

- **Transport** – emissions from transport sources are currently responsible for 11% of NMVOC emissions, with road transport accounting for more than half of this. During the 1990s, these emissions have declined significantly due to the increased use of catalytic converters and fuel switching from petrol to diesel cars. Between 2008 and 2009, emissions from passenger cars fell by 36% due to the assumed improvements in catalyst repair rates.

- **Offshore oil and gas** – emissions from this sector have increased substantially with the growth of the UK's offshore activities, and stem primarily from tanker loading/unloading.

Other sources of NMVOCs include:

- Gas leakage from the national gas distribution networks;
- Evaporative losses from the distribution and marketing of petrol;
- Waste treatment and disposal contribute;
- Natural and agricultural sources.

Emissions of NMVOCs for England, Wales, Scotland and Northern Ireland are summarised in the tables and graphs below. **Figure 2-32** shows the split of emissions between the four Devolved Administrations for the entire time series with
Table 2-19 presenting this split as a percentage for 1990 and 2011. **Table 2-20** shows per capita emissions for 1990 and 2011.

Figure 2-32 UK NMVOC Emissions by Devolved Administration, 1990-2011

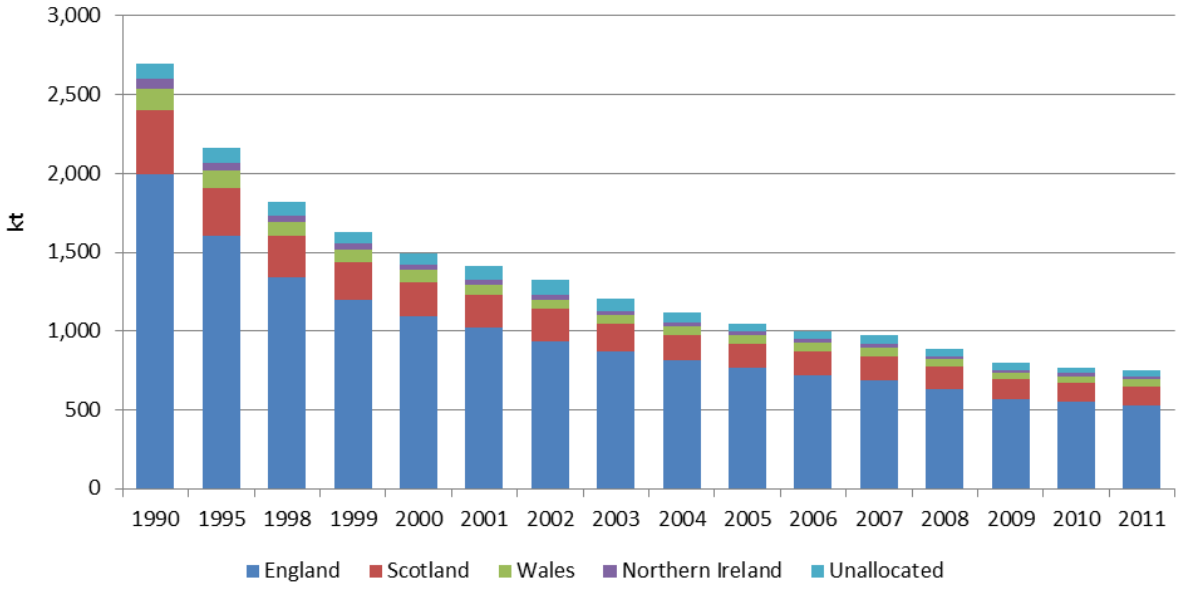


Table 2-19 Proportion of UK NMVOC Emissions by Devolved Administration

Year	England	Scotland	Wales	Northern Ireland	Unallocated
1990	74%	15%	5%	2%	3%
2011	70%	16%	6%	2%	5%

Table 2-20 Emissions of NMVOC per capita by Devolved Administration (kg/head)

Year	England	Scotland	Wales	Northern Ireland	UK
1990	41.8	80.4	47.5	40.5	47.1
2011	10.0	23.2	13.8	10.1	11.9

2.4.1 England NMVOC Inventory by Sector, 1990-2011

The table and graph below give a summary of the NMVOC emissions in England by broad NFR sector categories. The disaggregation of these categories is available in Appendix A (see Sector Category column).

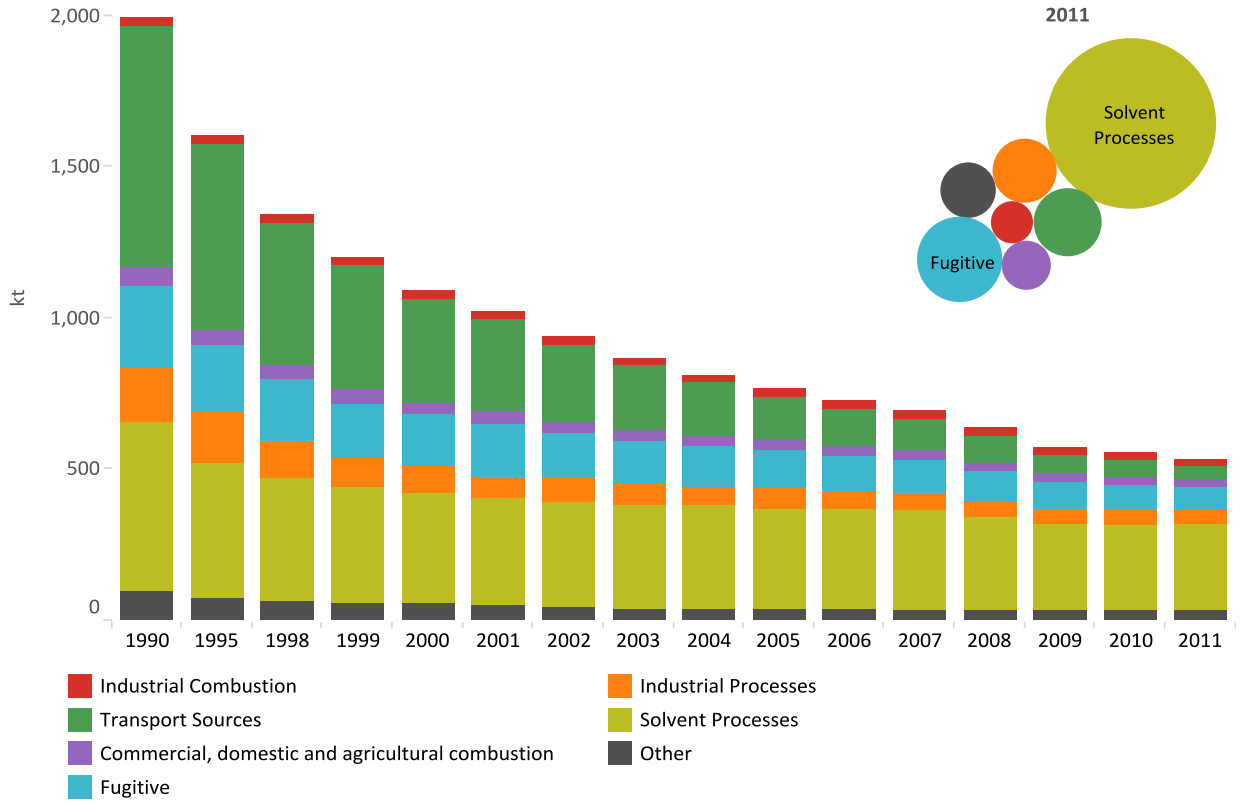
Table 2-21 England Emissions of NMVOC by Sector, 1990-2011

	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Industrial Combustion	24.5	25.1	25.3	24.9	24.7	24.9	24.6	23.9	23.8	24.3	23.0	23.8	22.1	18.4	19.4	17.9
Transport Sources	803.2	620.2	471.1	412.7	344.6	306.8	258.4	214.5	178.2	148.5	125.7	104.9	89.7	65.7	55.2	46.8
Commercial, domestic and agricultural combustion	58.0	42.3	43.0	44.6	37.9	35.7	32.4	31.3	30.1	28.2	26.8	26.4	26.9	25.5	26.0	24.4
Fugitive	270.9	228.7	207.7	183.1	173.5	174.5	152.8	141.3	134.2	130.2	118.1	114.1	101.7	95.2	86.1	73.5
Industrial Processes	183.5	167.3	120.5	89.1	85.8	74.8	73.7	70.6	62.4	59.7	53.6	54.7	46.8	41.9	43.7	41.5
Solvent Processes	555.7	449.0	414.8	391.8	370.3	357.0	350.3	345.2	345.2	339.6	338.4	331.4	311.9	289.7	288.2	293.9
Other [1]	97.5	71.6	59.7	55.4	53.9	47.9	46.5	40.8	38.2	36.9	37.6	35.5	34.6	33.4	32.4	31.1
Total	**1,993**	**1,604**	**1,342**	**1,202**	**1,091**	**1,022**	**939**	**868**	**812**	**767**	**723**	**691**	**634**	**570**	**551**	**529**

Units: kilotonnes

[1] "Other" for NMVOC includes emissions from Energy Industries, Agriculture, Waste as well as 1A5b, 7A.

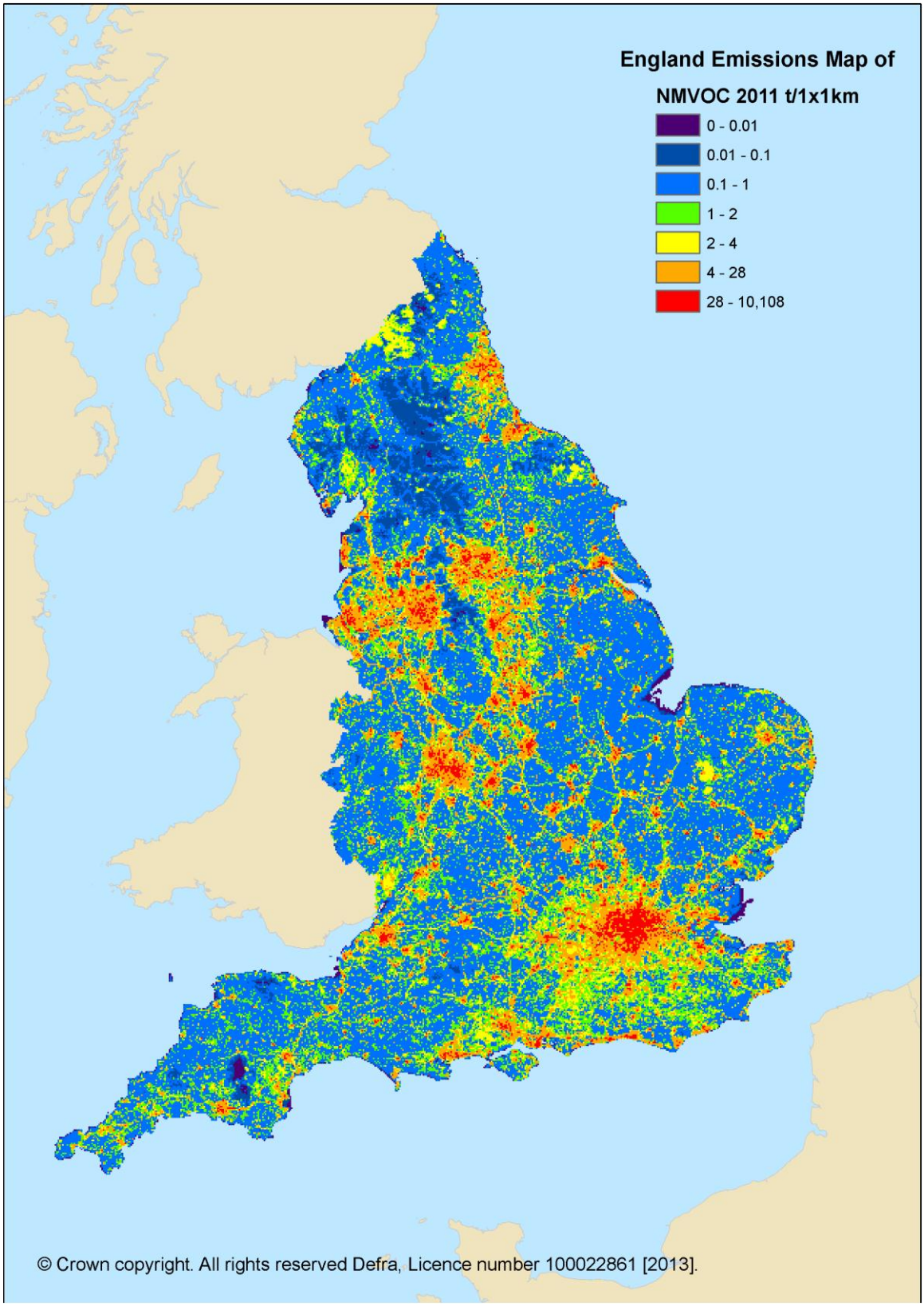
Figure 2-33 England NMVOC Emissions by Sector, 1990-2011



NMVOC emissions in England have declined by 73% since 1990 and account for 70% of the UK total. The solvent and other product use sector is a very significant source, accounting for 56% of the total in 2011. Emissions from this sector have reduced by 47% since 1990. Fugitive emissions from fuels account for 14% of

the total in 2011 with emissions down 73% since 1990. Further significant sources are road transport, including evaporative losses, which accounted for 7% of the total in 2011; emissions from this source have reduced by 95% since 1990 and industrial processes, which accounted for 8% of the total in 2011, with emissions down 77% since 1990.

Figure 2-34 Map of NMVOC Emissions in England, 2011



2.4.2 Scotland NMVOC Inventory by Sector, 1990-2011

The table and graph below give a summary of the NMVOC emissions in Scotland by broad NFR sector categories. The disaggregation of these categories is available in Appendix A (see Sector Category column).

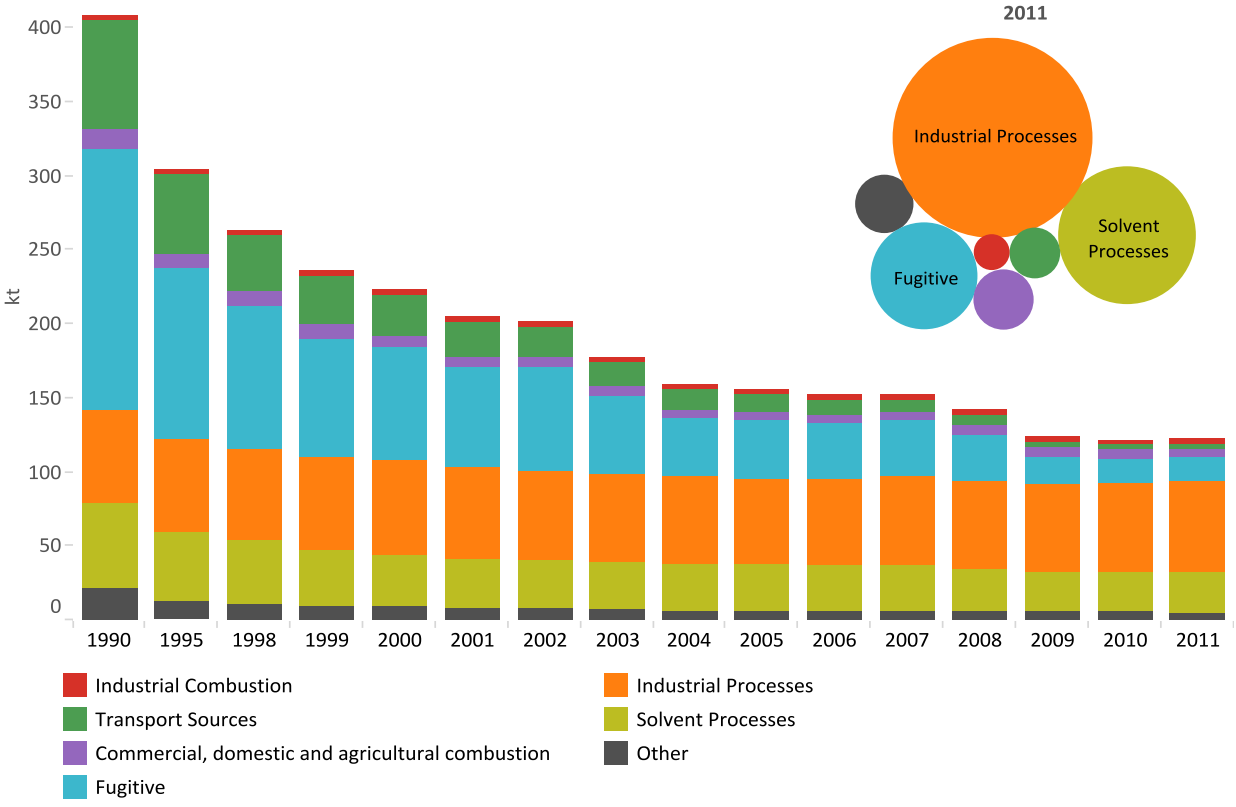
Table 2-22 Scotland Emissions of NMVOC by Sector, 1990-2011

	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Industrial Combustion	2.4	2.4	2.5	2.4	2.4	2.5	2.4	2.4	2.3	2.4	2.2	2.3	2.3	2.0	2.0	1.9
Transport Sources	74.3	54.5	39.1	33.6	27.9	24.7	20.9	17.4	14.7	12.5	10.9	9.3	8.0	5.2	4.5	3.9
Commercial, domestic and agricultural combustion	13.0	8.4	8.3	8.6	7.3	6.8	6.1	5.8	5.4	5.1	5.3	5.4	5.6	5.4	5.6	5.4
Fugitive	176.9	116.9	97.2	80.9	78.2	67.4	70.4	52.6	39.3	40.4	38.3	38.7	32.2	18.9	17.4	17.1
Industrial Processes	61.5	61.3	60.8	62.5	61.9	60.8	60.0	59.2	58.0	56.9	56.8	59.4	58.0	58.4	59.0	59.9
Solvent Processes	58.5	47.6	44.3	38.0	35.8	34.5	33.5	33.0	33.0	32.2	32.1	31.6	30.0	28.0	28.0	28.4
Other [1]	21.6	12.8	10.6	9.5	9.2	8.0	7.6	6.6	6.3	6.0	6.1	5.7	5.6	5.5	5.3	5.1
Total	**408**	**304**	**263**	**236**	**223**	**205**	**201**	**177**	**159**	**156**	**152**	**152**	**142**	**123**	**122**	**122**

Units: kilotonnes

[1] "Other" for NMVOC includes emissions from Energy Industries, Agriculture, Waste as well as 1A5b, 7A.

Figure 2-35 Scotland NMVOC Emissions by Sector, 1990-2011

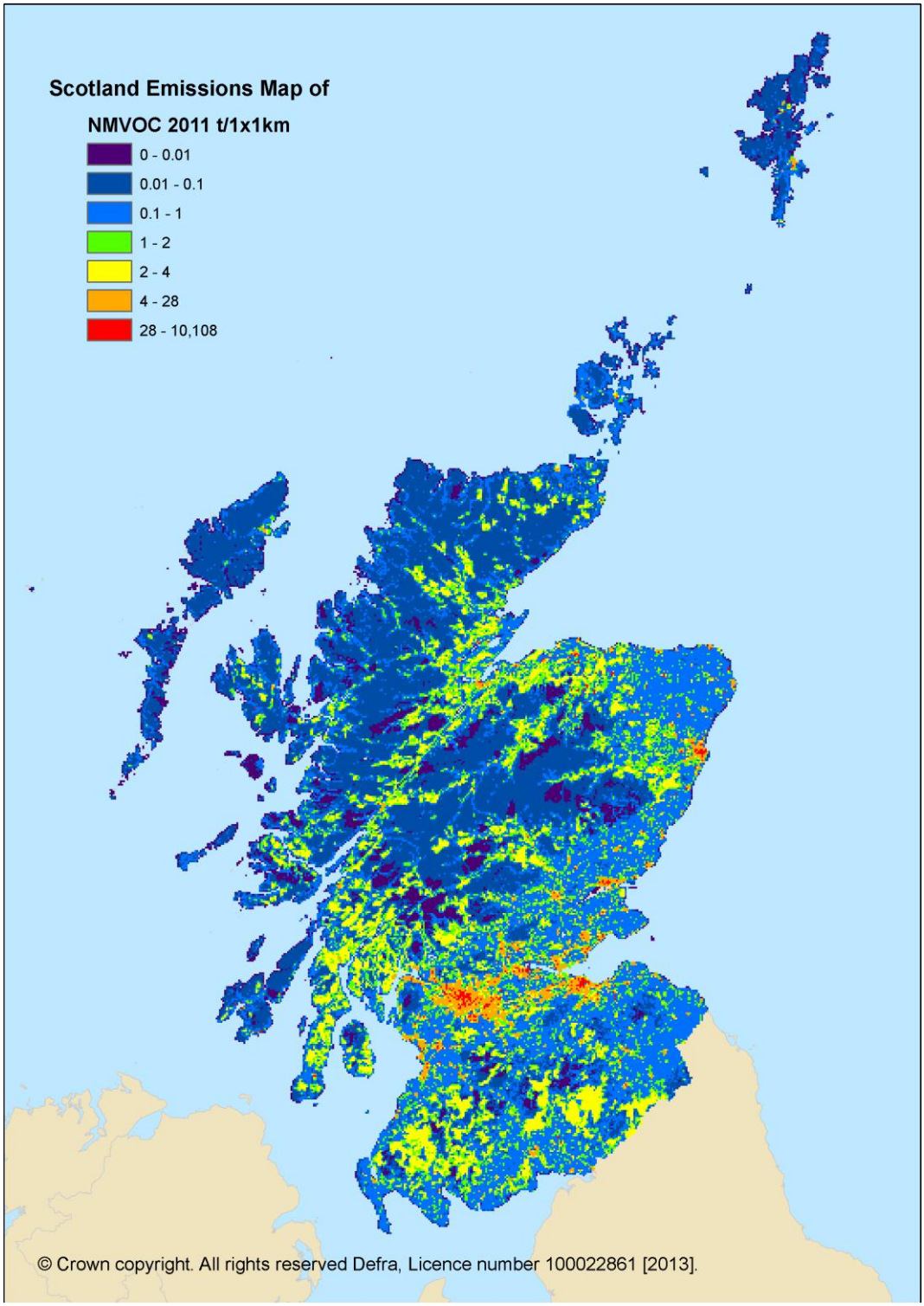


NMVOC emissions in Scotland have declined by 70% since 1990 and account for 16% of the UK total. Industrial processes are a significant source making up 49% of the total in 2011, with emissions down 3% since 1990. Industrial processes include food and drink emissions dominated by brewers and distilleries. This

is 45% of the Scottish total in 2011, up 26% since 1990. Other significant sources are solvents and other product use, which account for 23% of the total in 2011. Emissions from this source are down 51% since 1990. Fugitive emissions from fuels make up 14% of the total in 2011, which have reduced by 90% since 1990. Road transport is also a relatively significant source, including evaporative losses, accounting for 2% of the total in 2011 with emissions down 96% since 1990.

On a per capita basis, Scottish emissions are around 70% higher than the UK average, due to the high contribution of NMVOC emissions from food and drink processes.

Figure 2-36 Map of NMVOC Emissions in Scotland, 2011



2.4.3 Wales NMVOC Inventory by Sector, 1990-2011

The table and graph below give a summary of the NMVOC emissions in Wales by broad NFR sector categories. The disaggregation of these categories is available in Appendix A (see Sector Category column).

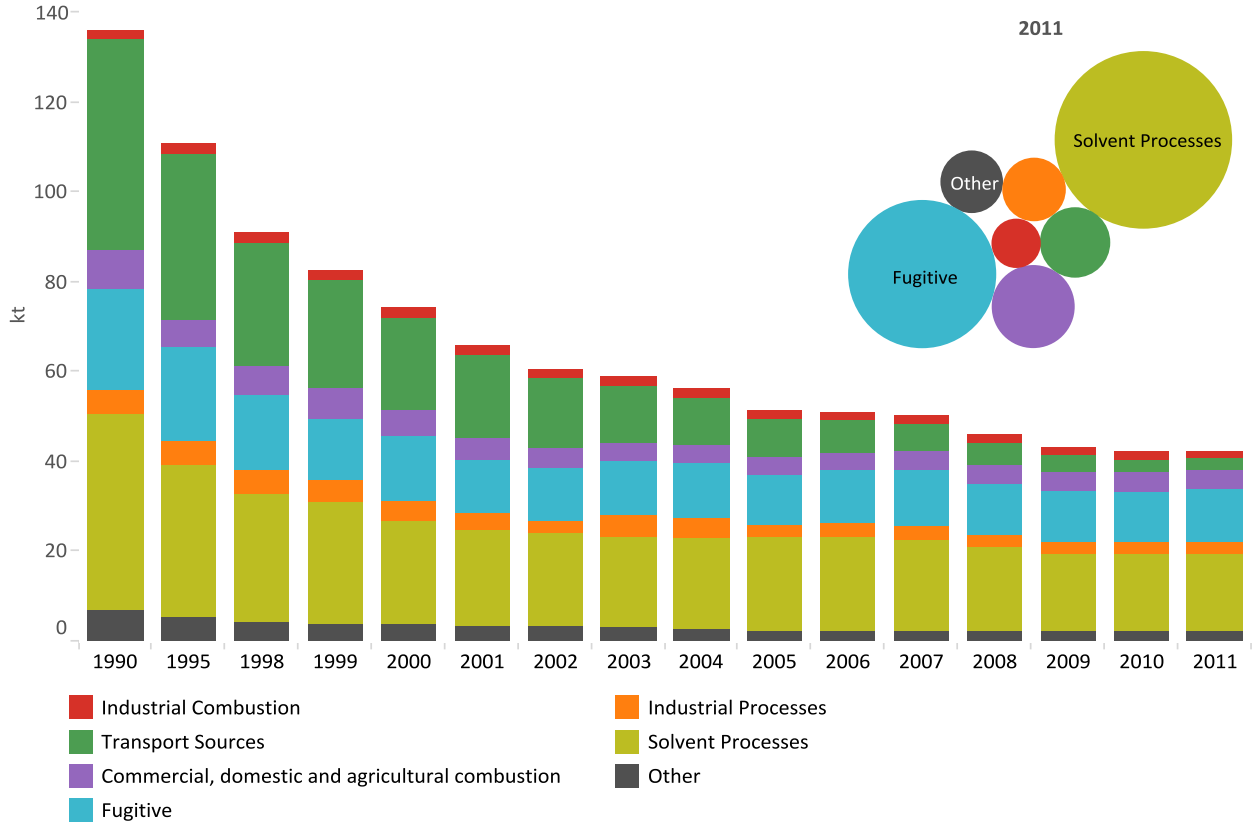
Table 2-23 Wales Emissions of NMVOC by Sector, 1990-2011

	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Industrial Combustion	1.9	2.0	2.0	2.1	2.2	2.1	2.1	2.2	1.9	1.8	1.8	1.8	1.7	1.4	1.4	1.4
Transport Sources	47.0	37.1	27.8	24.2	20.6	18.3	15.5	12.8	10.6	8.7	7.4	6.2	5.3	3.8	3.2	2.8
Commercial, domestic and agricultural combustion	8.1	5.9	6.2	6.6	5.2	4.7	4.1	3.9	3.7	3.5	3.6	3.8	4.0	3.8	3.9	3.8
Fugitive	22.9	21.0	17.0	14.0	15.0	12.2	12.3	11.8	12.5	11.6	12.3	13.2	11.6	12.1	11.7	12.2
Industrial Processes	5.5	5.2	5.0	4.6	4.1	3.3	2.2	4.8	4.2	2.3	2.5	2.4	2.3	2.1	2.3	2.2
Solvent Processes	43.7	34.2	28.7	27.4	23.1	21.7	21.0	20.7	20.7	21.1	21.2	20.7	19.1	17.6	17.4	17.5
Other [1]	6.9	5.3	4.3	3.9	3.9	3.3	3.3	2.9	2.6	2.4	2.5	2.4	2.4	2.2	2.2	2.2
Total	**136**	**111**	**91**	**83**	**74**	**66**	**61**	**59**	**56**	**51**	**51**	**50**	**46**	**43**	**42**	**42**

Units: kilotonnes

[1] "Other" for NMVOC includes emissions from Energy Industries, Agriculture, Waste as well as 1A5b, 7A.

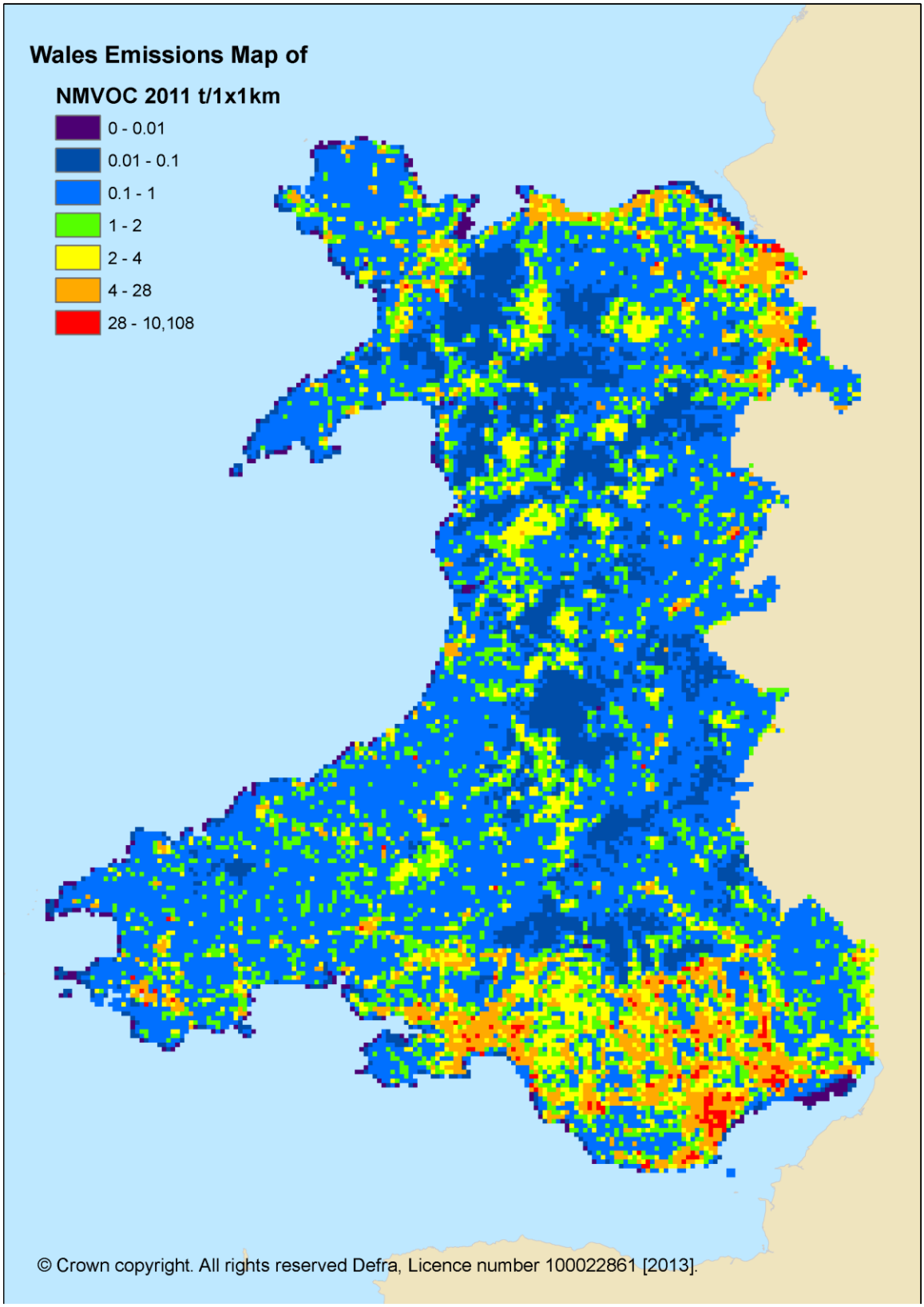
Figure 2-37 Wales NMVOC Emissions by Sector, 1990-2011



NMVOC emissions in Wales have declined by 69% since 1990 and account for 6% of the UK total. Solvents and other product use accounts for 42% of the Wales NMVOC inventory total in 2011; emissions from this source have reduced by 60% since 1990. Fugitive emissions from fuels are another significant source of emissions

making up 29% of the total in 2011. Emissions from this source have been reduced by 47% since 1990. Road transport is an important source of emissions, including evaporative losses, accounting for 5% of the total in 2011. Emissions from this source are down 95% since 1990. Industrial processes account for 5% of the total in 2011, with emissions down 59% since 1990.

Figure 2-38 Map of NMVOC Emissions in Wales, 2011



2.4.4 Northern Ireland NMVOC Inventory by Sector, 1990-2011

The table and graph below give a summary of the NMVOC emissions in Northern Ireland by broad NFR sector categories. The disaggregation of these categories is available in Appendix A (see Sector Category column).

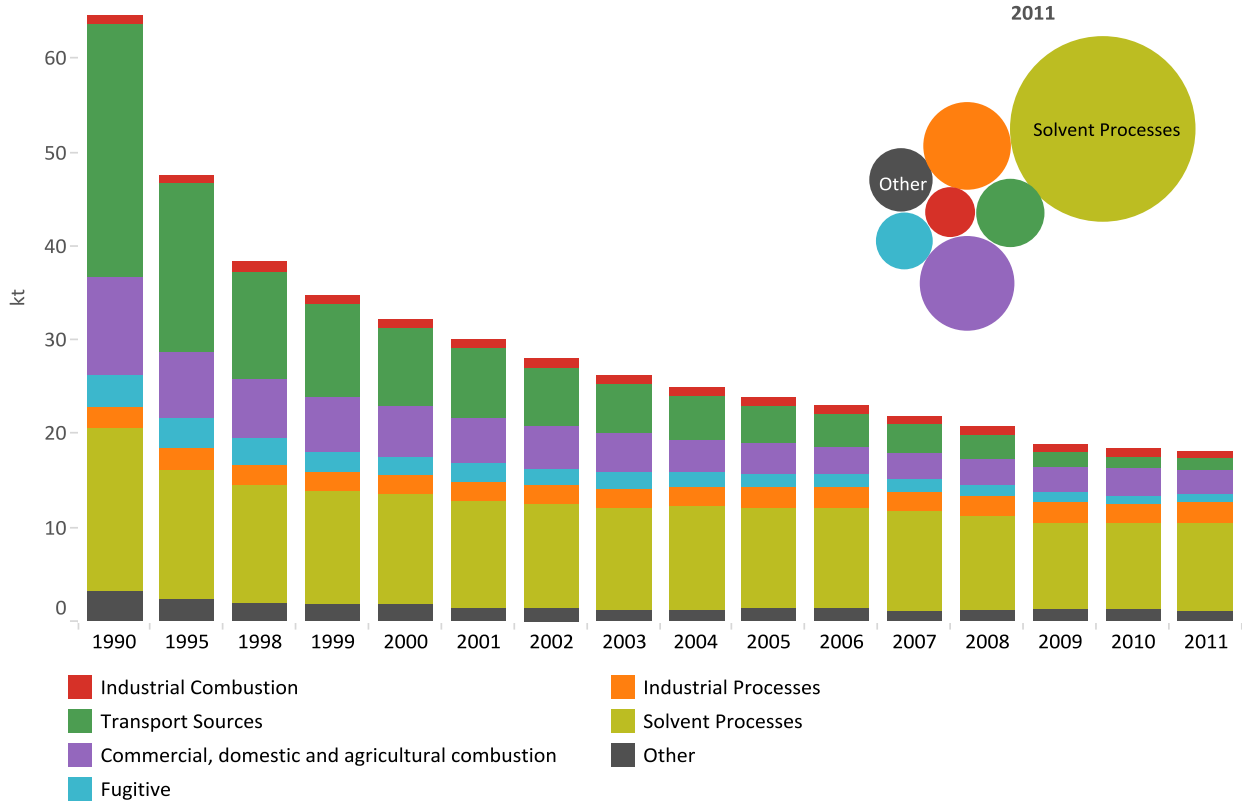
Table 2-24 Northern Ireland Emissions of NMVOC by Sector, 1990-2011

	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Industrial Combustion	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.8	0.7	0.7	0.7
Transport Sources	27.0	17.9	11.5	10.0	8.4	7.6	6.3	5.5	4.8	4.1	3.5	3.1	2.7	1.7	1.5	1.3
Commercial, domestic and agricultural combustion	10.3	7.0	6.1	5.7	5.3	4.7	4.4	3.9	3.3	3.0	2.8	2.6	2.7	2.6	2.6	2.5
Fugitive	3.4	3.2	2.9	2.2	2.1	1.9	1.8	1.8	1.7	1.5	1.4	1.4	1.1	1.1	0.9	0.9
Industrial Processes	2.4	2.4	2.2	2.1	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.1	2.1	2.1	2.1	2.1
Solvent Processes	17.3	13.8	12.7	12.2	11.9	11.5	11.3	11.1	11.1	11.0	10.9	10.8	10.2	9.5	9.4	9.6
Other [1]	3.2	2.4	2.0	1.8	1.8	1.5	1.4	1.2	1.3	1.4	1.4	1.1	1.2	1.2	1.2	1.1
Total	**65**	**48**	**38**	**35**	**32**	**30**	**28**	**26**	**25**	**24**	**23**	**22**	**21**	**19**	**18**	**18**

Units: kilotonnes

[1] "Other" for NMVOC includes emissions from Energy Industries, Agriculture, Waste as well as 1A5b, 7A.

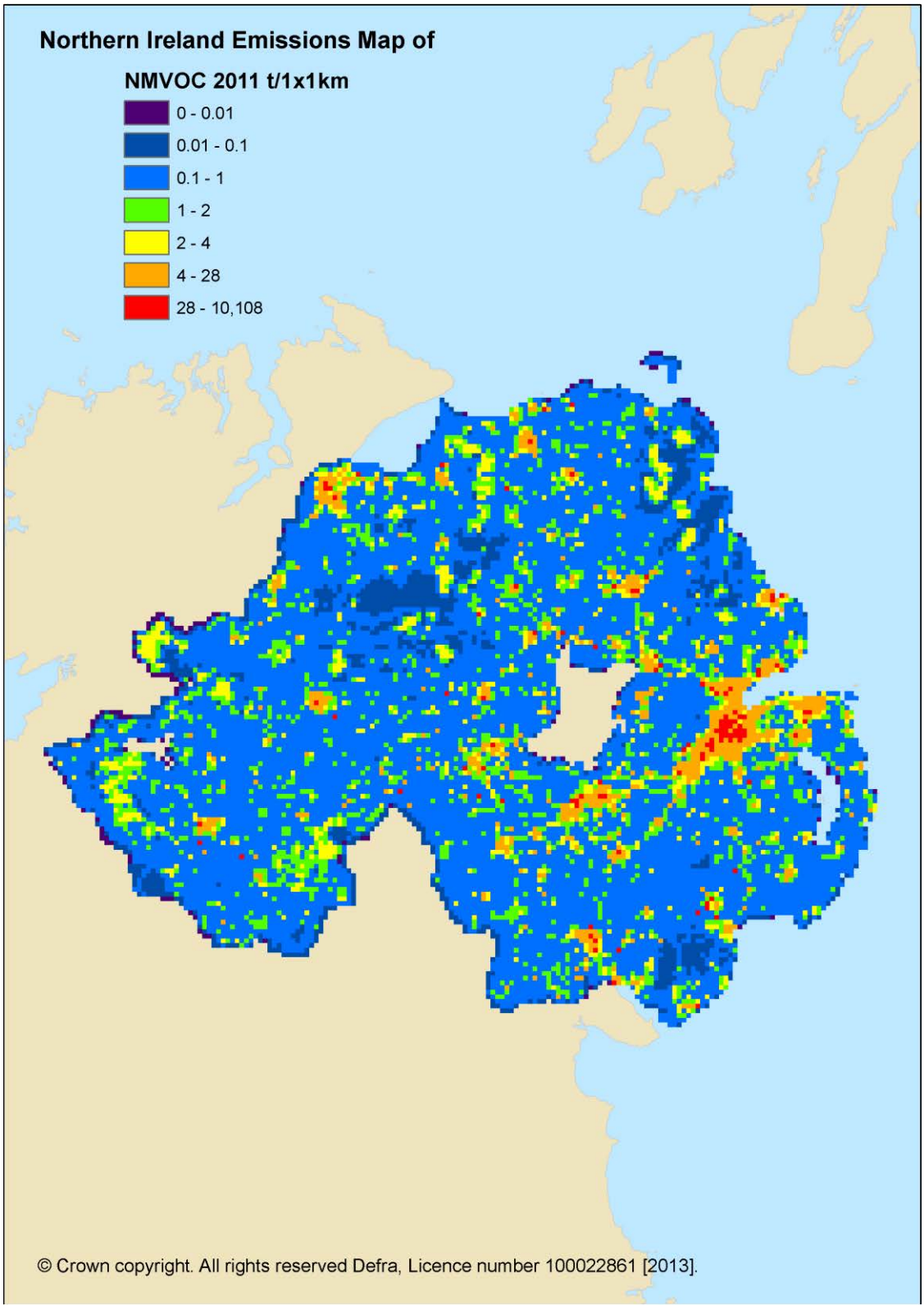
Figure 2-39 Northern Ireland NMVOC Emissions by Sector, 1990-2011



NMVOC emissions in Northern Ireland have declined by 72% since 1990 and account for 2% of the UK total. Solvent and other product use are a major source making up 53% of the NMVOC inventory total in Northern Ireland in 2011. Emissions from this source are down 45% since 1990. Another significant source is

commercial, domestic and agricultural combustion, which accounts for 14% of the NMVOC inventory total in Northern Ireland in 2011. Emissions from this source are down 76% since 1990. The food and drink sector accounted for 11% of the total in 2011 and emissions from this source have increased by 12% since 1990 due to increased emissions from whisky production. Road transport sources, including evaporative losses, make up 6% of the total in 2011 with a 96% reduction since 1990. Another important source is fugitive emissions from fuels accounting for 5% of the total in 2011. This source of emission has reduced by 74% since 1990.

Figure 2-40 Map of NMVOC Emissions in Northern Ireland, 2011



2.5 PARTICULATE MATTER AS PM_{10}

PM_{10} is a measure of the size distribution of the particles emitted to air and represents the material with an aerodynamic diameter less than 10 micro meters. PM_{10} in the atmosphere arises from primary and secondary sources:

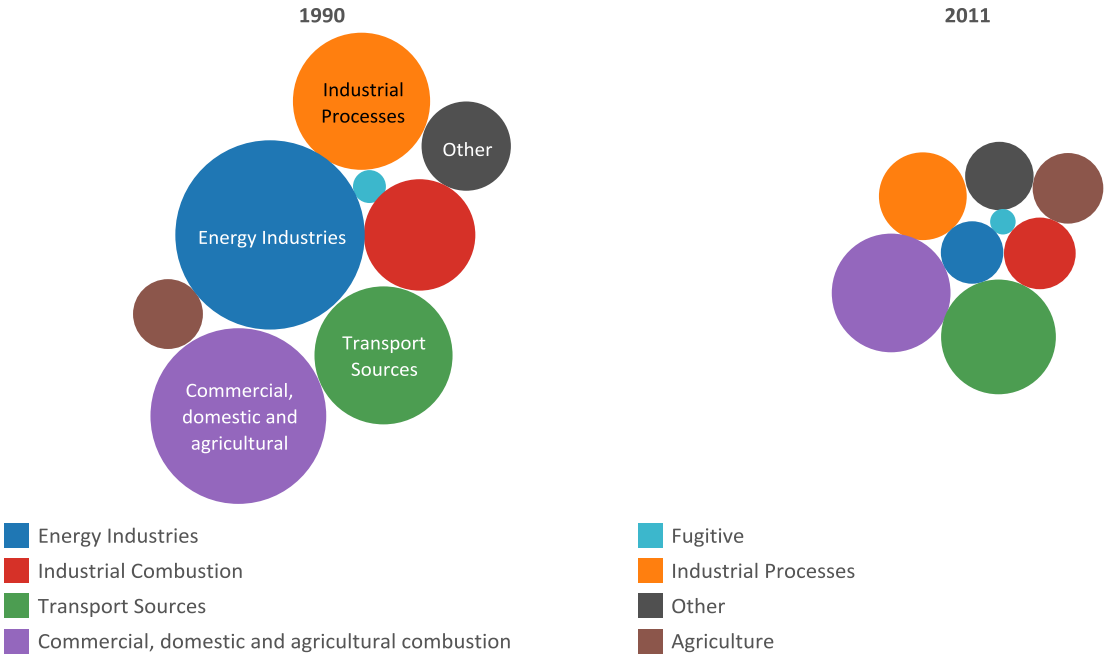
Primary Sources
Direct emissions of particulate matter into the atmosphere arise from a wide range of sources such as fuel combustion, surface erosion and wind-blown dusts and mechanical break-up in, for example, quarrying and construction sites.

Secondary Sources
Particulate matter may be formed in the atmosphere through reactions of other pollutants such as sulphur dioxide, nitrogen oxides and ammonia to form solid sulphates and nitrates, as well as organic aerosols formed from the oxidation of NMVOCs.

These inventories only consider primary sources. For further information on secondary particulates see the Air Quality Expert Group's Report on particulate matter in the United Kingdom (AQEG, 2005) and on fine particulate matter ($PM_{2.5}$) in the United Kingdom (AQEG, 2012).

UK emission estimates for primary PM_{10} are presented below for 1990 and 2011 (**Figure 2-41**). UK emissions have decreased by 59% since 1990 as indicated by the change in area between the 1990 and 2011 graph. This is mainly due to improved abatement of industrial and power generation emission sources and a general reduction in coal use as an energy source across many economic sectors. Emissions from power generation accounted for 26% of total emissions in 1990 and only 6% of total emissions in 2011, decreasing by 61% between 1990 and 2011.

Figure 2-41 UK PM_{10} Emissions by Sector (1990 and 2011)



The main sources of primary PM_{10} are briefly described below:

- **Road transport** – diesel engines typically emit a greater mass of particulates per vehicle kilometre than petrol engines. Particulate emissions also arise from all vehicles through brake and tyre wear as well as from the re-entrainment of dust from road surfaces caused by vehicle movements, but

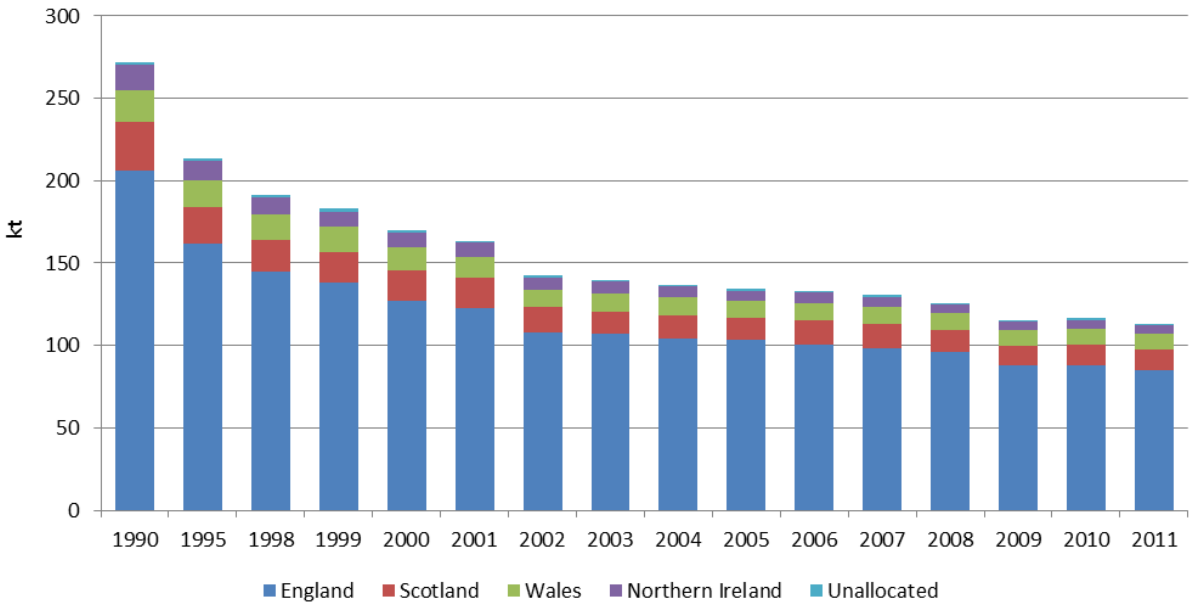
estimates of particulate emissions from re-suspension are not included within UK inventory PM_{10} totals.

- **Stationary combustion** – coal combustion has historically been the main source of particulate emissions in the UK, but restrictions in the use of coal for domestic combustion through the Clean Air Acts has led to other sources becoming more important nationally. Domestic coal is still a significant source in Northern Ireland, some smaller towns and villages, and in areas associated with the coal industry. Other fossil fuels emit PM_{10} with combustion of wood, gas oil and fuel oil all contributing significantly to UK emissions. In general, particles emitted from fuel combustion are of a smaller size than from other sources.

- **Industrial processes** – particulates are emitted from a wide range of industrial processes including: the production of metals, cement, lime, coke and chemicals, bulk handling of dusty materials, construction, mining and quarrying. Whilst emission monitoring results are now widely available for stack and other point-source emissions of particulates from regulated industrial processes, the quantification of diffuse and fugitive emissions from industrial sources is more difficult. Few UK measurements are available for these fugitive releases but there have been substantial improvements in the estimation of PM_{10} emissions from industrial processes in recent years.

Emissions of PM_{10} for England, Wales, Scotland and Northern Ireland are summarised in the tables and graphs below. **Figure 2-42** shows the split of emissions between the four Devolved Administrations for the entire time series with **Table 2-25** presenting this split as a percentage for 1990 and 2011. **Table 2-26** shows per capita emissions for 1990 and 2011.

Figure 2-42 UK PM_{10} Emissions by Devolved Administration, 1990-2011



Emissions from power stations have declined despite a significant growth in electricity generation capacity, due to a shift in the fuel mix for power generation from coal to natural gas, nuclear and renewable generation, and also due to abatement being fitted at coal-fired power stations. For example, the installation of flue gas desulphurisation (FGD) at a number of plants has reduced particulate matter emissions substantially.

Emissions from road transport have varied across the time-series as a number of factors have combined. The main source of road transport emissions is exhaust gases from diesel engines. Emissions from diesel vehicles have been growing due to the growth in heavy-duty vehicle traffic and the move towards more diesel cars. Since around 1992, however, emissions from diesel vehicles have been decreasing due to the penetration of new vehicles meeting tighter PM_{10} emission regulations ("Euro standards" for diesel vehicles were first

introduced in 1992), while non-exhaust emissions from tyre and brake wear and road abrasion are increasingly more important.

Among the non-combustion and non-transport sources, the major emissions are from industrial processes, the most important of which is quarrying whose emission rates have remained fairly constant. Other industrial processes, including the manufacture of steel, cement, lime, coke, and primary and secondary non-ferrous metals, are collectively important sources of particulate matter although emissions from individual sectors are relatively insignificant.

Table 2-25 Proportion of UK PM_{10} Emissions by Devolved Administration

Year	England	Scotland	Wales	Northern Ireland	Unallocated
1990	76%	11%	7%	6%	1%
2011	75%	11%	8%	5%	1%

Table 2-26 Emissions of PM_{10} per capita by Devolved Administration (kg/head)

Year	England	Scotland	Wales	Northern Ireland	UK
1990	4.3	5.8	6.8	9.7	4.8
2011	1.6	2.3	3.0	2.9	1.8

2.5.1 England PM_{10} Inventory by Sector, 1990-2011

The table and graph below give a summary of the PM_{10} emissions in England by broad NFR sector categories. The disaggregation of these categories is available in Appendix A (see Sector Category column).

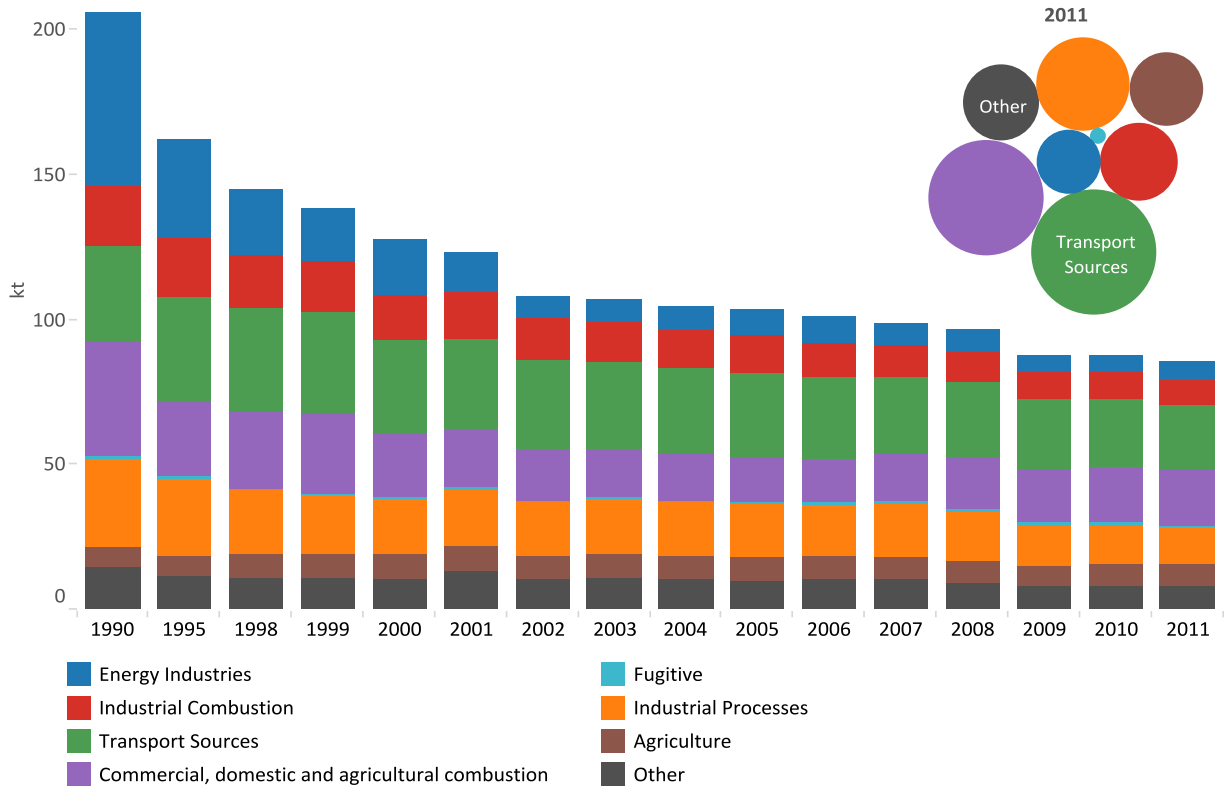
Table 2-27 England Emissions of PM_{10} by Sector, 1990-2011

	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Energy Industries	59.9	34.0	22.4	18.2	19.0	13.4	7.4	7.6	7.8	8.6	8.9	7.3	7.6	6.0	5.6	5.9
Industrial Combustion	21.0	20.1	18.6	17.1	15.5	15.6	14.7	14.1	13.4	13.1	11.6	11.1	10.3	9.2	9.5	8.7
Transport Sources	32.5	36.6	35.7	35.3	32.2	31.5	30.5	29.9	29.4	28.9	28.1	26.8	25.6	24.4	23.8	22.5
Commercial, domestic and agricultural combustion	39.5	25.3	26.1	27.5	22.0	20.3	17.6	16.5	16.1	15.6	15.5	16.0	18.2	18.2	19.1	19.1
Fugitive	0.4	0.2	0.3	0.3	0.2	0.2	0.3	0.4	0.4	0.6	0.6	0.6	0.5	0.3	0.5	0.4
Industrial Processes	30.8	26.7	21.8	20.0	19.0	19.2	18.5	18.8	18.0	17.8	17.1	18.4	16.7	13.8	13.0	12.5
Agriculture	7.6	7.4	8.7	8.7	8.9	9.4	8.5	8.7	8.9	8.6	8.7	8.3	8.3	7.6	8.0	7.8
Other [1]	14.2	11.7	11.0	11.0	10.6	13.3	10.4	10.8	10.2	10.0	10.3	10.2	9.1	8.2	8.3	8.3
Total	**206.0**	**162.1**	**144.6**	**138.1**	**127.4**	**122.7**	**108.1**	**106.8**	**104.2**	**103.2**	**100.7**	**98.6**	**96.2**	**87.8**	**87.8**	**85.2**

Units: kilotonnes

[1] "Other" for PM_{10} includes emissions from Solvent Processes, Waste as well as 1A5b, 7A.

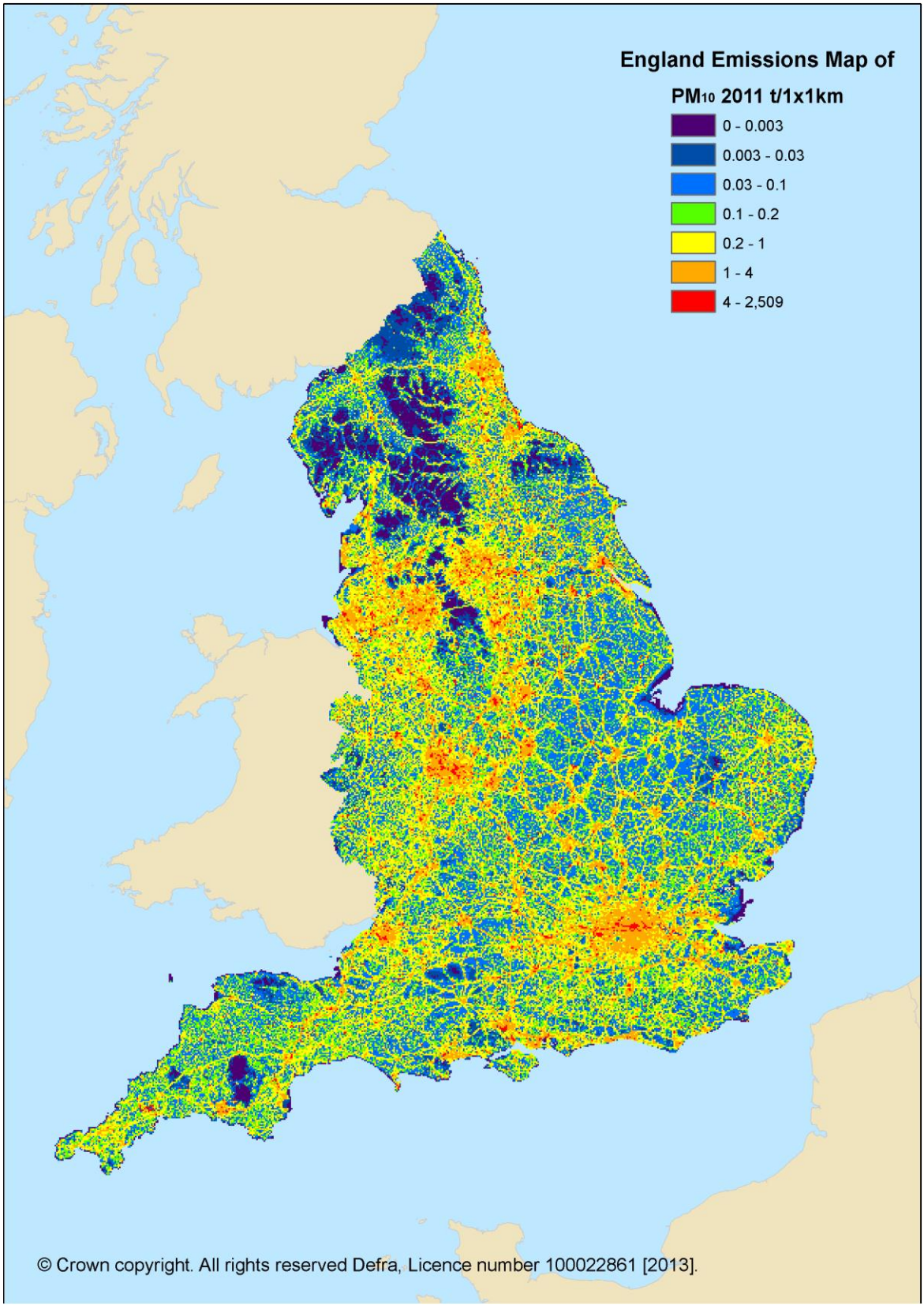
Figure 2-43 England PM_{10} Emissions by Sector, 1990-2011



PM_{10} emissions in England have declined by 59% since 1990 and account for 75% of the UK total in 2011. 23% of PM_{10} emissions in England come from road transport sources (down by 32% since 1990), whilst 22% stem

from commercial, domestic and agricultural combustion (mainly of coal and solid fuels, down by 52% since 1990). Emissions from power generation were 28% of the England total emission in 1990, but have been significantly reduced to 6% of the England total in 2011.

Figure 2-44 Map of PM_{10} Emissions in England, 2011



2.5.2 Scotland PM_{10} Inventory by Sector, 1990-2011

The table and graph below give a summary of the PM_{10} emissions in Scotland by broad NFR sector categories. The disaggregation of these categories is available in Appendix A (see Sector Category column).

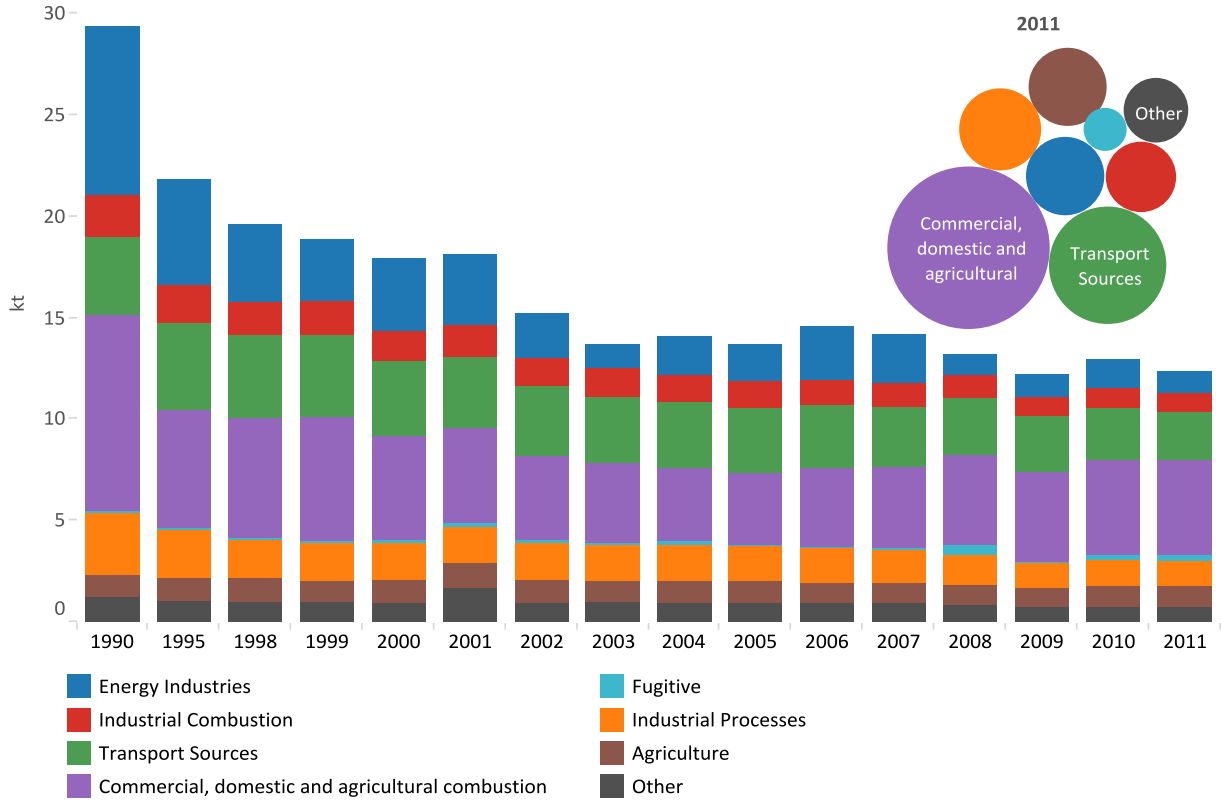
Table 2-28 Scotland Emissions of PM_{10} by Sector, 1990-2011

	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Energy Industries	8.3	5.2	3.8	3.1	3.6	3.5	2.2	1.2	1.9	1.8	2.6	2.4	1.0	1.1	1.4	1.1
Industrial Combustion	2.1	1.9	1.6	1.6	1.5	1.6	1.4	1.3	1.3	1.3	1.2	1.2	1.1	1.0	1.0	0.9
Transport Sources	3.9	4.3	4.1	4.1	3.6	3.5	3.4	3.3	3.3	3.2	3.1	2.9	2.8	2.7	2.6	2.4
Commercial, domestic and agricultural combustion	9.7	5.8	5.9	6.2	5.1	4.7	4.1	3.9	3.6	3.5	3.9	4.0	4.4	4.4	4.6	4.6
Fugitive	0.1	0.0	0.0	0.1	0.2	0.1	0.2	0.1	0.1	0.1	0.0	0.0	0.5	0.1	0.3	0.3
Industrial Processes	3.0	2.3	1.9	1.8	1.7	1.7	1.7	1.7	1.7	1.7	1.6	1.6	1.4	1.2	1.2	1.2
Agriculture	1.2	1.2	1.2	1.1	1.2	1.3	1.2	1.1	1.2	1.1	1.1	1.1	1.1	1.0	1.1	1.1
Other [1]	1.2	1.0	1.0	1.0	0.9	1.7	0.9	1.0	0.9	0.9	0.9	0.9	0.8	0.8	0.7	0.7
Total	**29.4**	**21.8**	**19.6**	**18.8**	**17.9**	**18.1**	**15.2**	**13.6**	**14.0**	**13.7**	**14.6**	**14.2**	**13.2**	**12.1**	**12.9**	**12.3**

Units: kilotonnes

[1] "Other" for PM_{10} includes emissions from Solvent Processes, Waste as well as 1A5b, 7A.

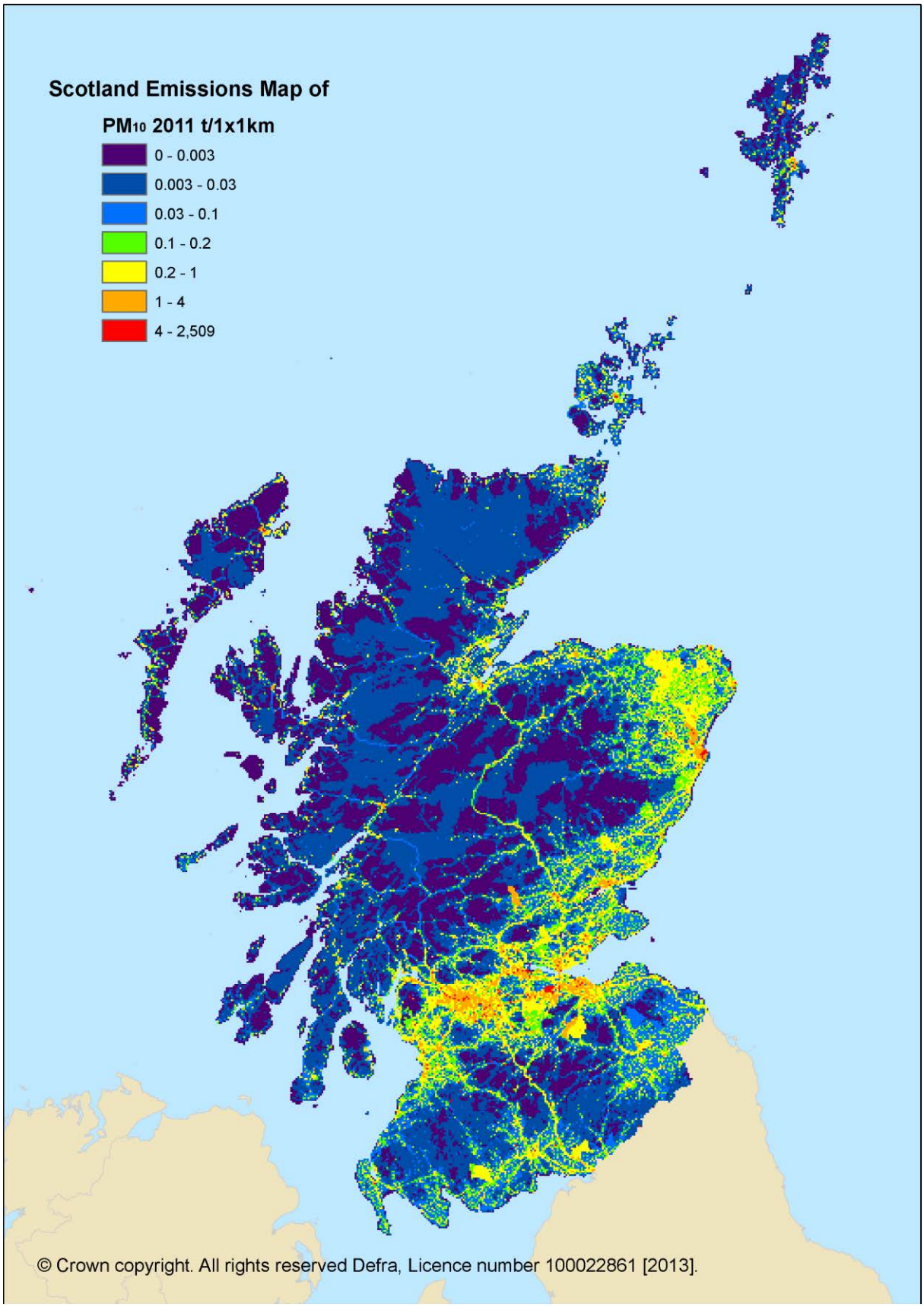
Figure 2-45 Scotland PM_{10} Emissions by Sector, 1990-2011



PM_{10} emissions in Scotland have declined by 58% since 1990 and accounted for 11% of the UK total in 2011. 17% of PM_{10} emissions in Scotland come from road transport sources (down by 32% since 1990), whilst 38% stem from commercial, domestic and agricultural combustion (mainly of coal and solid fuels, down by 52%

since 1990). Emissions from power generation were 25% of the Scotland total emission in 1990, but have been reduced to 8% of the Scotland total in 2011.

Figure 2-46 Map of PM_{10} Emissions in Scotland, 2011



2.5.3 Wales PM_{10} Inventory by Sector, 1990-2011

The table and graph below give a summary of the PM_{10} emissions in Wales by broad NFR sector categories. The disaggregation of these categories is available in Appendix A (see Sector Category column).

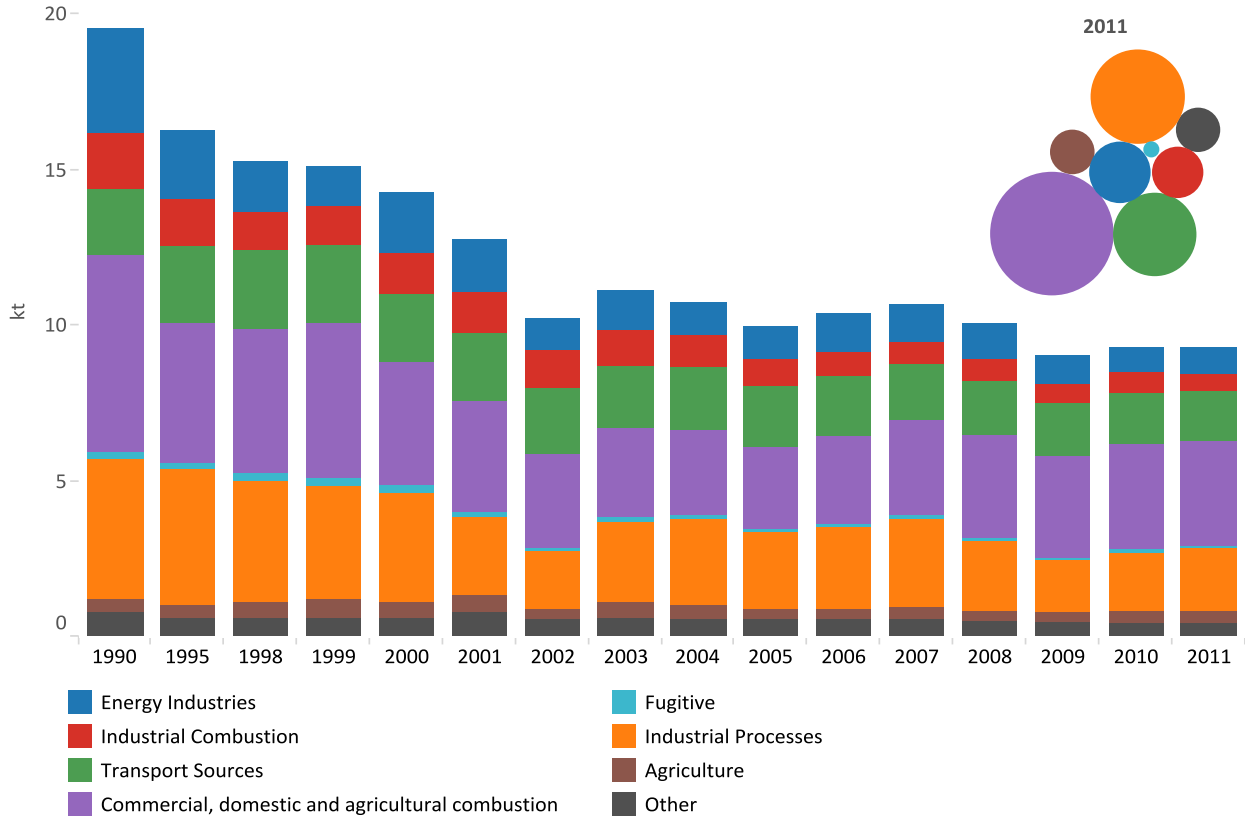
Table 2-29 Wales Emissions of PM_{10} by Sector, 1990-2011

	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Energy Industries	3.3	2.2	1.7	1.3	2.0	1.7	1.0	1.2	1.0	1.0	1.2	1.2	1.1	0.9	0.8	0.8
Industrial Combustion	1.8	1.6	1.2	1.3	1.3	1.3	1.2	1.2	1.0	0.9	0.8	0.8	0.7	0.6	0.7	0.6
Transport Sources	2.1	2.5	2.5	2.5	2.2	2.2	2.1	2.1	2.0	2.0	1.9	1.8	1.8	1.7	1.6	1.5
Commercial, domestic and agricultural combustion	6.4	4.5	4.7	5.0	3.9	3.5	3.0	2.8	2.7	2.6	2.8	3.0	3.3	3.3	3.3	3.4
Fugitive	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Industrial Processes	4.5	4.4	3.9	3.6	3.5	2.5	1.9	2.6	2.8	2.5	2.6	2.8	2.2	1.6	1.9	2.0
Agriculture	0.5	0.4	0.6	0.7	0.6	0.6	0.4	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Other [1]	0.7	0.6	0.6	0.6	0.6	0.8	0.6	0.6	0.5	0.5	0.6	0.6	0.5	0.4	0.4	0.4
Total	**19.5**	**16.3**	**15.3**	**15.1**	**14.3**	**12.7**	**10.2**	**11.1**	**10.7**	**10.0**	**10.4**	**10.7**	**10.1**	**9.0**	**9.3**	**9.3**

Units: kilotonnes

[1] "Other" for PM_{10} includes emissions from Solvent Processes, Waste as well as 1A5b, 7A.

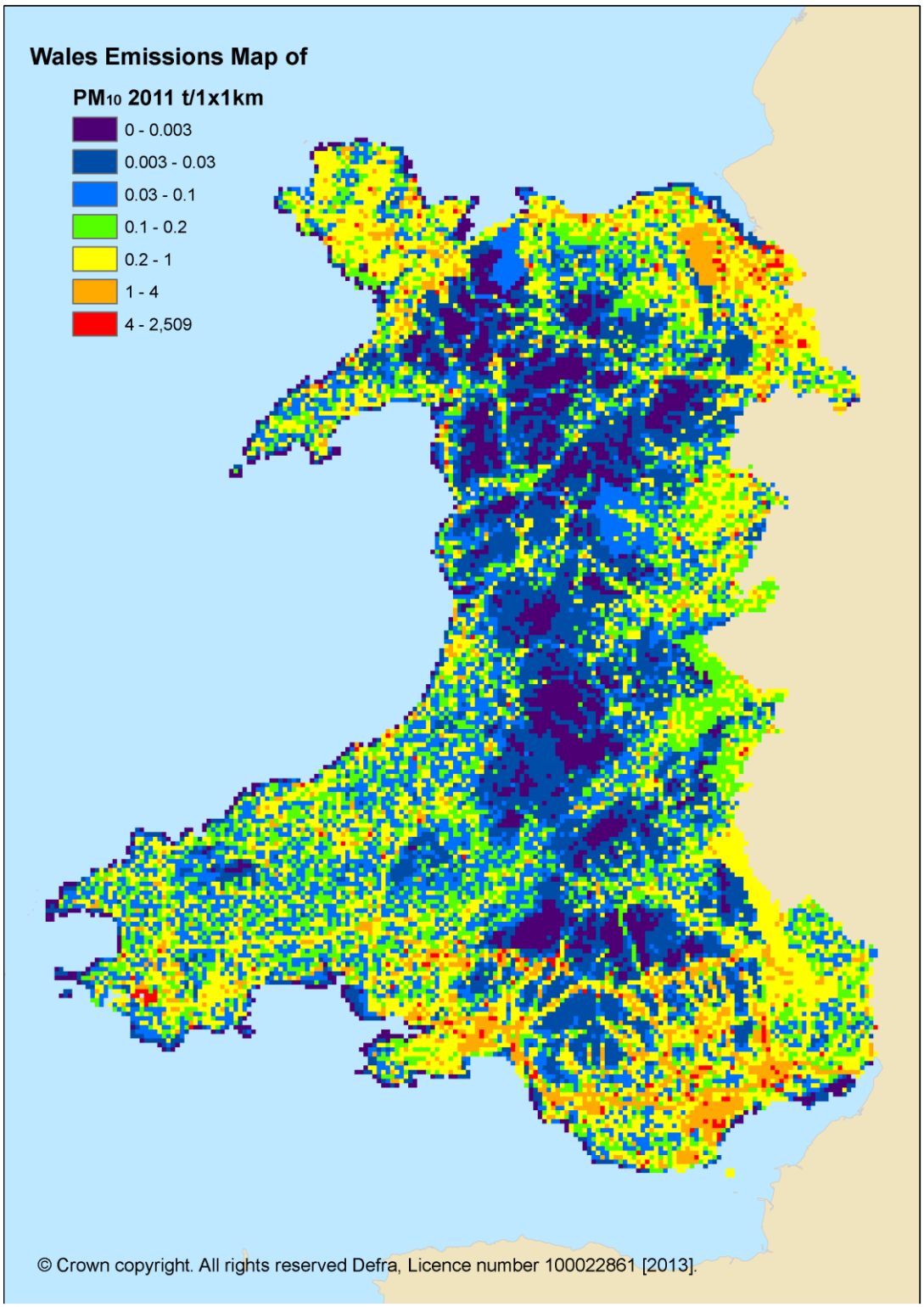
Figure 2-47 Wales PM_{10} Emissions by Sector, 1990-2011



PM_{10} emissions in Wales have declined by 52% since 1990 and accounted for 8% of the UK total in 2011. Commercial, domestic and agricultural combustion sources accounted for 37% of Welsh emissions in 2011,

mainly from combustion of solid fuels; these emissions have declined by 47% since 1990. In 2011, 14% of PM_{10} emissions in Wales come from road transport sources (down by 27% since 1990), whilst emissions from power generation accounted for 4% of the Wales total in 2011, down 86% on 1990 emissions. Heavy industry plays a more significant role in the Wales PM_{10} inventory than in other parts of the UK, with key contributions to the 2011 total from iron & steel production (15%), other manufacturing combustion (3%) and quarrying and mining (4%). Welsh per capita emissions of PM_{10} are 70% higher than the UK average, due primarily to emissions from iron and steel manufacture.

Figure 2-48 Map of PM_{10} Emissions in Wales, 2011



2.5.4 Northern Ireland PM_{10} Inventory by Sector, 1990-2011

The table and graph below give a summary of the PM_{10} emissions in Northern Ireland by broad NFR sector categories. The disaggregation of these categories is available in Appendix A (see Sector Category column).

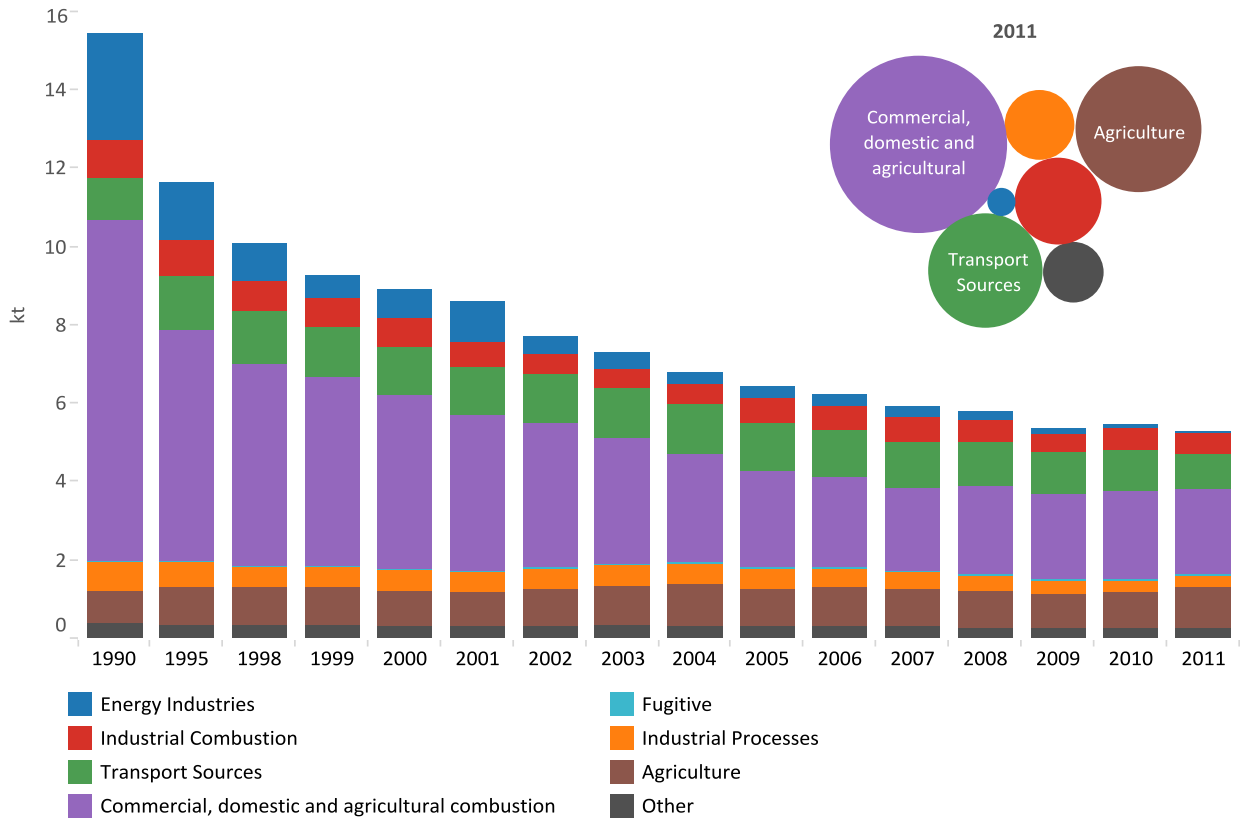
Table 2-30 Northern Ireland Emissions of PM_{10} by Sector, 1990-2011

	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Energy Industries	2.7	1.5	1.0	0.6	0.8	1.0	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.1	0.1	0.1
Industrial Combustion	1.0	0.9	0.8	0.7	0.7	0.7	0.5	0.5	0.5	0.7	0.6	0.7	0.6	0.5	0.6	0.5
Transport Sources	1.1	1.4	1.3	1.3	1.2	1.2	1.2	1.3	1.2	1.2	1.2	1.1	1.1	1.1	1.0	0.9
Commercial, domestic and agricultural combustion	8.7	5.9	5.1	4.8	4.4	4.0	3.7	3.2	2.8	2.5	2.3	2.1	2.3	2.2	2.2	2.1
Fugitive	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Industrial Processes	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.3	0.3	0.3
Agriculture	0.9	1.0	1.0	1.0	0.9	0.9	1.0	1.0	1.1	1.0	1.0	1.0	1.0	0.9	0.9	1.1
Other [1]	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Total	**15.4**	**11.6**	**10.1**	**9.3**	**8.9**	**8.6**	**7.7**	**7.3**	**6.8**	**6.4**	**6.2**	**5.9**	**5.8**	**5.4**	**5.4**	**5.3**

Units: kilotonnes

[1] "Other" for PM_{10} includes emissions from Solvent Processes, Waste as well as 1A5b, 7A.

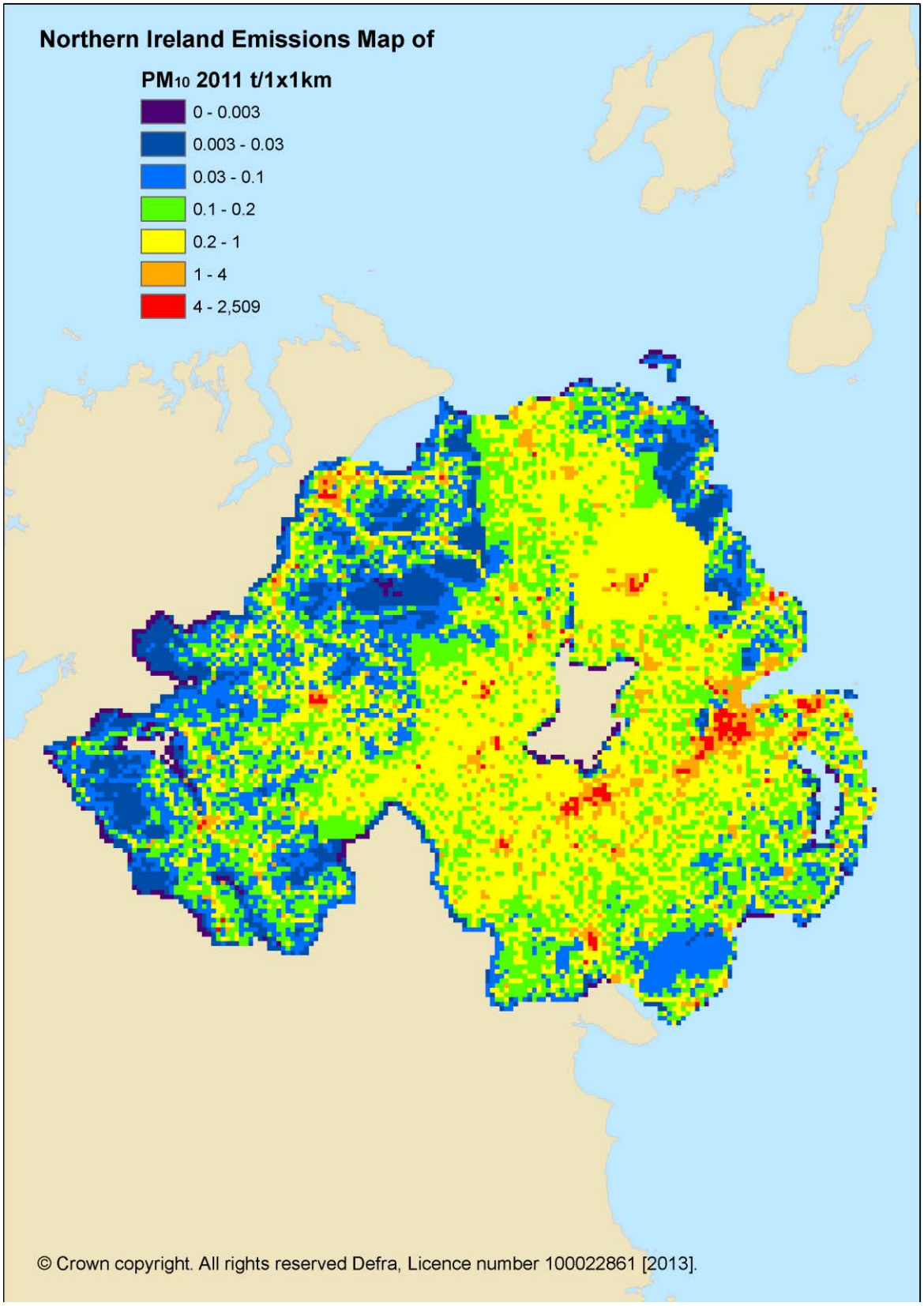
Figure 2-49 Northern Ireland PM_{10} Emissions by Sector, 1990-2011



PM_{10} emissions in Northern Ireland have declined by 66% since 1990 and accounted for 5% of the UK total in 2011. 15% of PM_{10} emissions in Northern Ireland come from road transport sources (down by 15% since 1990), whilst 41% stem from commercial, domestic and agricultural combustion (mainly of coal and solid

fuels), down by 75% since 1990. Emissions from power generation were 18% of the total emissions in 1990, but have been reduced to 1% of the Northern Ireland total in 2011. Per capita emissions of PM_{10} in Northern Ireland are 63% higher than the UK average due to the high contribution of emissions from domestic combustion and agricultural mobile machinery.

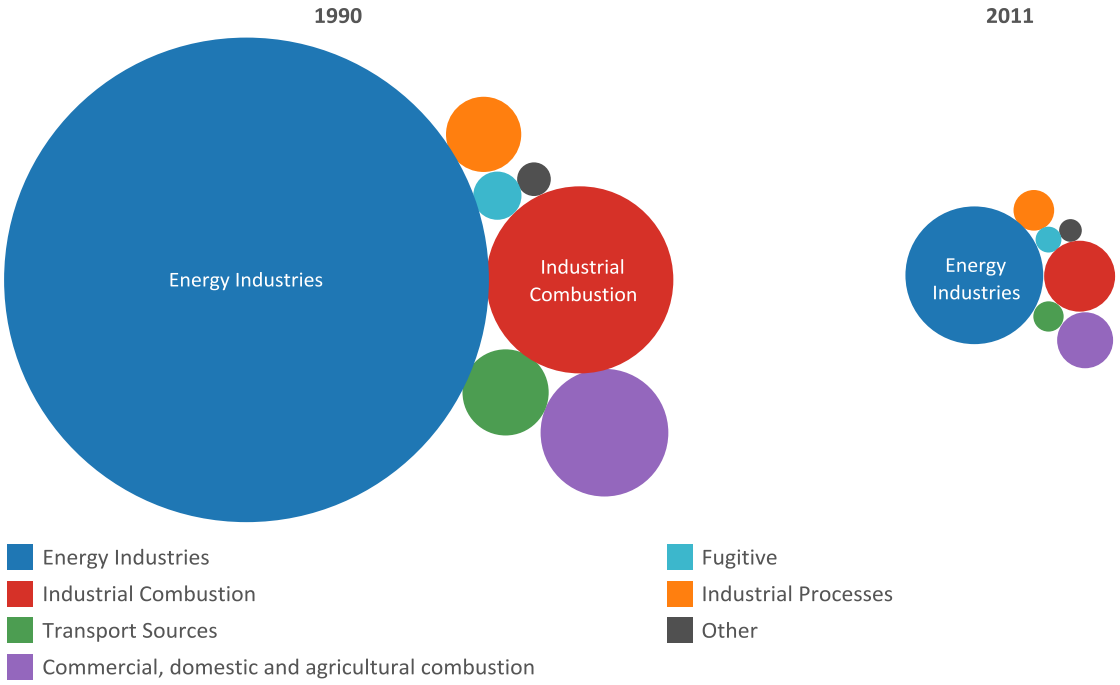
Figure 2-50 Map of PM_{10} Emissions in Northern Ireland, 2011



2.6 SULPHUR DIOXIDE

Since 1990 there has been a substantial overall reduction of 90% in SO_2 emissions from across the UK, mainly due to a decline in emissions from combustion of sulphur-containing solid fuels and petroleum products. UK emission estimates for sulphur dioxide are presented below for 1990 and 2011 (**Figure 2-51**Error! Reference source not found.). This reduction in emissions is indicated by the change in area between the 1990 and 2011 graph.

Figure 2-51 UK Sulphur Dioxide Emissions by Sector (1990 and 2011)



Emissions from combustion of petroleum products have fallen significantly due to the decline in fuel oil use and the reduction in the sulphur content of gas oil and DERV (diesel fuel specifically used for road vehicles). The reduced sulphur content of gas oil is particularly significant in sectors such as domestic heating, commercial heating and off-road sources where gas oil is used extensively.

Fuel combustion accounted for 92% of total UK SO_2 emissions in 2011 with the sulphur arising from the fuel itself. The SO_2 emission can be calculated from knowledge of the sulphur content of the fuel and from information on the amount of sulphur retained in the ash. Published fuel consumption data (DECC, 2012a), sulphur contents of liquid fuels (UKPIA, 2012a) and data from coal producers regarding sulphur contents of coals enable reliable estimates to be produced. The main combustion sources are:

- **Power generation** – power stations accounted for 44% of UK SO_2 emissions in 2011. Historically coal-fired stations have been the most important source, but the gradual change in fuel mix of UK power stations (to more nuclear and gas-fired plant) and improvements in generation efficiency and these reductions will continue in the near future as more CCGT stations are built, coal-fired stations are taken off-line and FGD is fitted to remaining coal-fired power plant.

- **Industrial Combustion** – emissions of SO_2 from industry result from the combustion of coal and oil, some refinery processes and the production of sulphuric acid and other chemicals. Between 1990 and 2011 emissions from industrial combustion sources have fallen by 86%, primarily due to the decline in energy-intensive heavy industries such as iron & steel manufacturing. In addition, UK industry has gradually switched from coal and oil-based fuels in favour of natural gas, as it provides a cleaner, cheaper energy source.

In 2011, road transport emissions accounted for less than 1% of the total SO_2 emissions. Previously this source was more significant, but a tightening of fuel standards during the 1990s and more recently due to the EU Fuel Quality Directive and its amendments has led to a significant decline in emissions due to the reduction in the sulphur content of DERV. The reduction in the sulphur content of gas oil (to 0.1% by mass from January 2008 onwards) has also reduced emissions from off-road vehicles.

Emissions from the domestic, commercial and agricultural sector have also declined since 1990, reflecting the major changes in fuel mix from oil and coal to gas. Emissions from waste incinerators have reduced significantly during the 1990s due to the introduction of stricter emission standards forcing the closure of old-design incinerators and their replacement with more modern plant with improved abatement.

Emissions of SO_2 for England, Wales, Scotland and Northern Ireland are summarised in the tables and graphs below. **Figure 2-52** shows the split of emissions between the four Devolved Administrations for the entire time series with **Table 2-31** presenting this split as a percentage for 1990 and 2011. **Table 2-32** shows per capita emissions for 1990 and 2011.

Figure 2-52 UK Sulphur Dioxide Emissions by Devolved Administration, 1990-2011

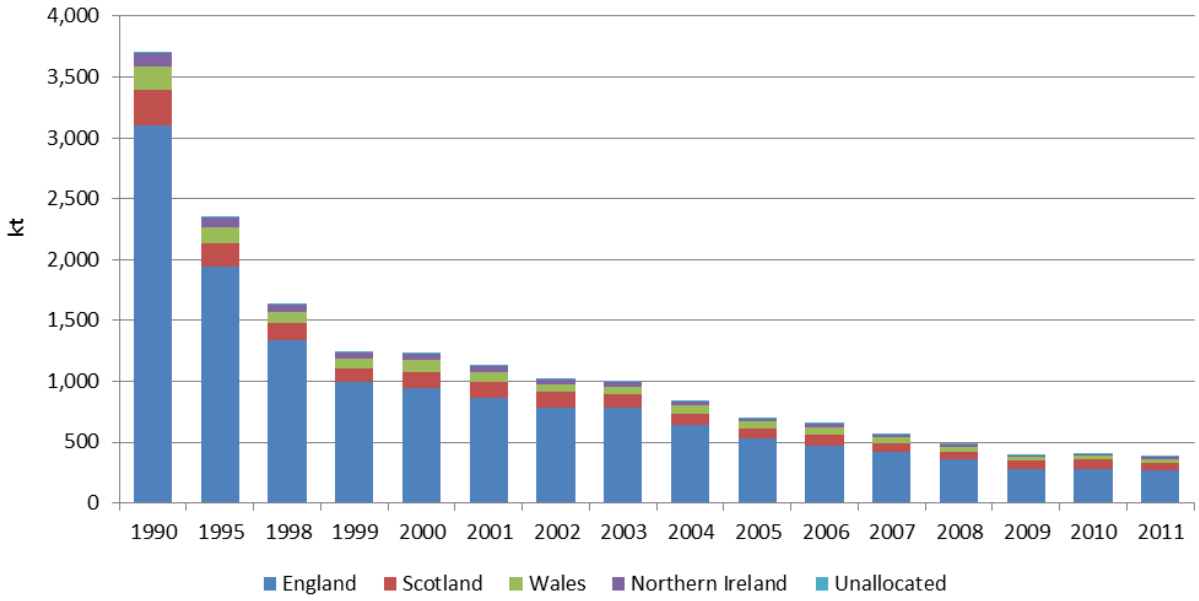


Table 2-31 Proportion of UK Sulphur Dioxide Emissions by Devolved Administration

Year	England	Scotland	Wales	Northern Ireland	Unallocated
1990	84%	8%	5%	3%	0%
2011	71%	16%	8%	4%	1%

Table 2-32 Emissions of Sulphur Dioxide per capita by Devolved Administration (kg/head)

Year	England	Scotland	Wales	Northern Ireland	UK
1990	65.0	58.8	65.3	70.3	64.8
2011	5.1	11.7	10.3	7.4	6.0

2.6.1 England Sulphur Dioxide Inventory by Sector, 1990-2011

The table and graph below give a summary of the SO_2 emissions in England by broad NFR sector categories. The disaggregation of these categories is available in Appendix A (see Sector Category column).

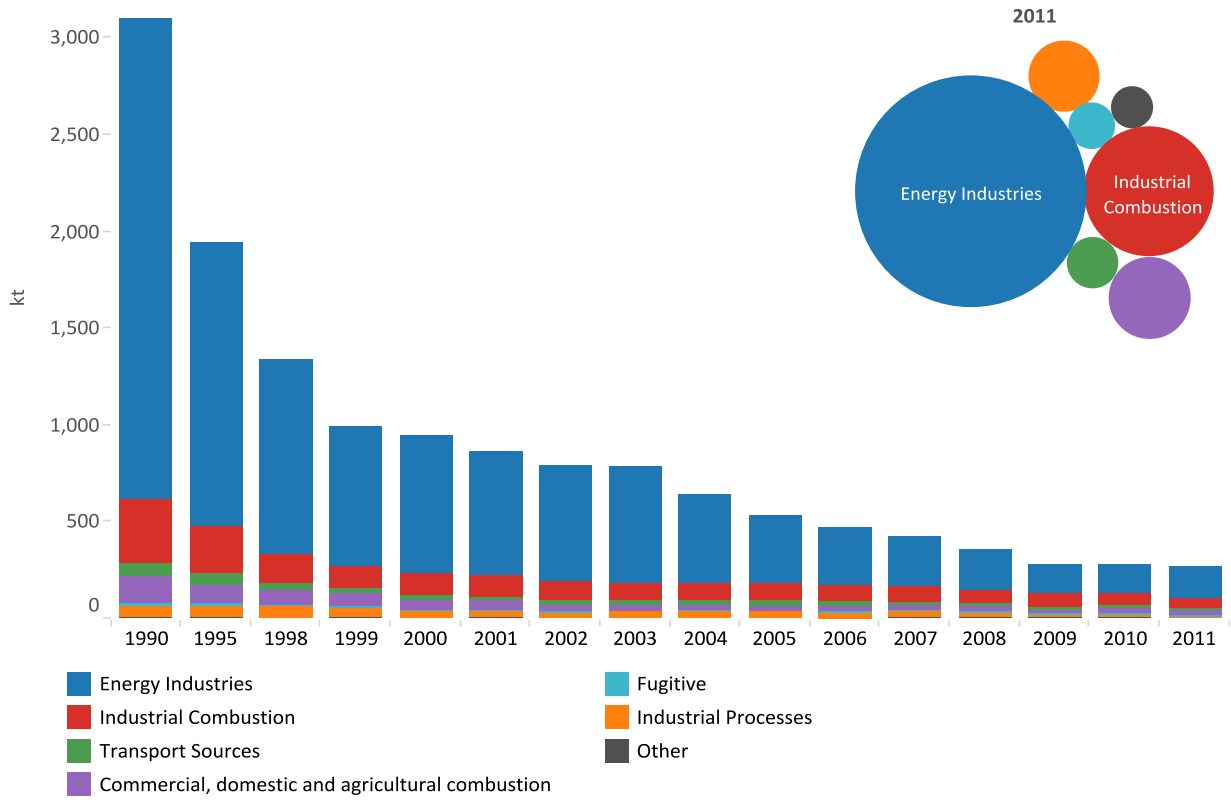
Table 2-33 England Emissions of Sulphur Dioxide by Sector, 1990-2011

	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Energy Industries	2,481	1,470	1,012	723	713	638	594	597	457	351	303	257	207	151	149	163
Industrial Combustion	331	241	149	114	108	109	95	87	89	92	81	76	72	64	61	51
Transport Sources	71	59	36	28	21	18	19	19	19	19	19	15	11	10	9	8
Commercial, domestic and agricultural combustion	132	96	70	64	51	49	36	32	29	25	23	23	24	22	22	20
Fugitive	16	9	7	6	6	7	5	7	8	7	7	10	9	8	11	7
Industrial Processes	57	62	63	53	42	38	35	35	36	36	35	33	25	18	16	15
Other [1]	13	8	4	4	4	5	4	4	4	4	4	8	8	7	7	5
Total	**3,100**	**1,945**	**1,341**	**993**	**945**	**863**	**786**	**780**	**643**	**533**	**473**	**421**	**356**	**280**	**275**	**270**

Units: kilotonnes

[1] "Other" for sulphur dioxide includes emissions from Solvent Processes, Agriculture, Waste as well as 1A5b, 7A.

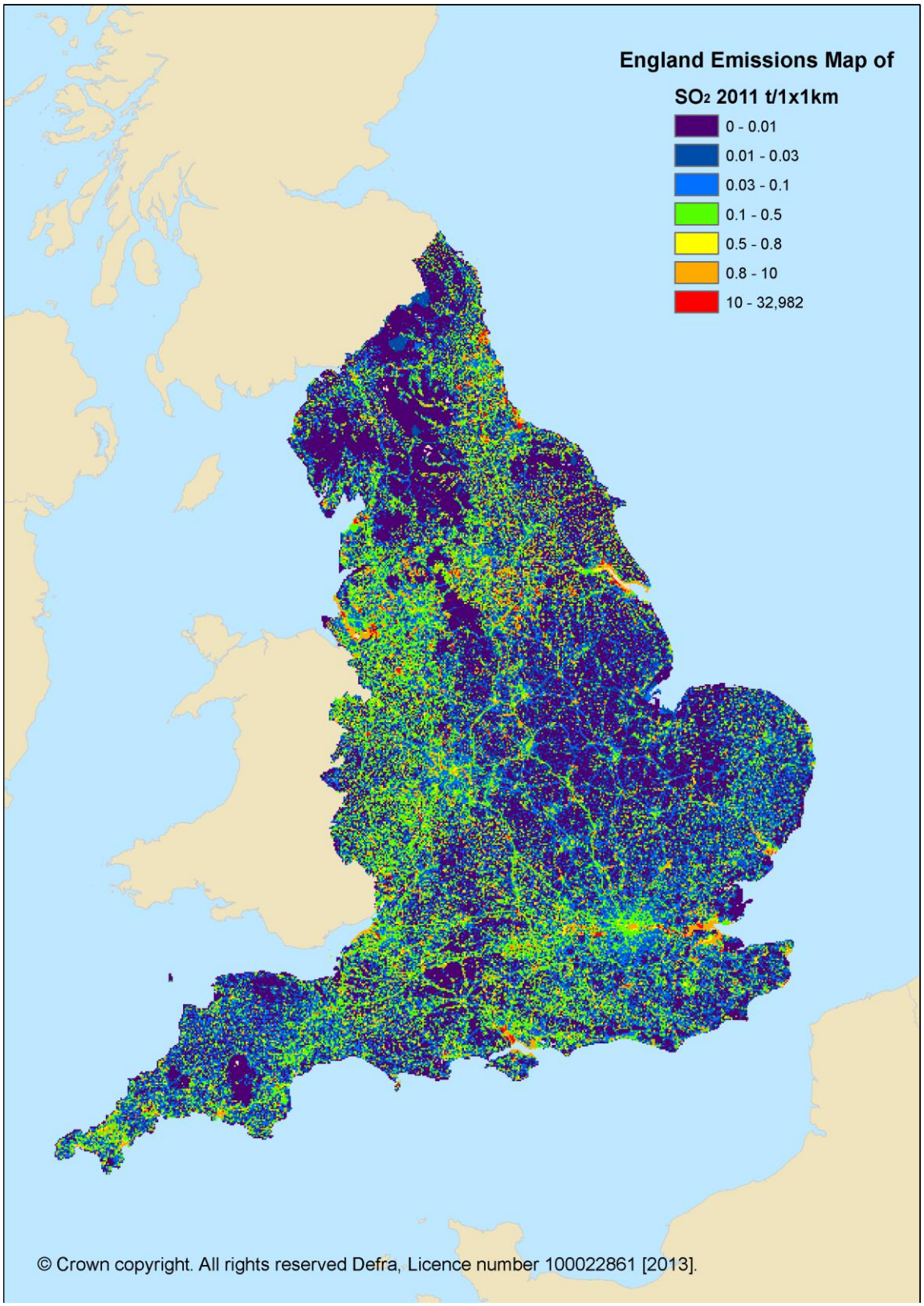
Figure 2-53 England Sulphur Dioxide Emissions by Sector, 1990-2011



Sulphur dioxide emissions in England have declined by 91% since 1990 and accounted for 71% of the UK total in 2011. Power generation is by far the most significant source, accounting for 44% of the England total in 2011 (mainly from the sulphur in coal and fuel oil), but due to the growth in gas and nuclear fuel use and the

installation of FGD plant at a number of coal-fired power stations, emissions from this source have reduced by 95% since 1990. 19% of SO_2 emissions in England are from industrial combustion (down by 85% since 1990), 15% from refineries (down 57% since 1990) whilst domestic combustion and national navigation contribute 6% and 2% of the total in 2011, respectively. Reductions in SO_2 emissions across all sectors are also due to the progress towards production of low-sulphur petroleum-based fuels such as gas oil (diesel) and burning oil.

Figure 2-54 Map of Sulphur Dioxide Emissions in England, 2011



2.6.2 Scotland Sulphur Dioxide Inventory by Sector, 1990-2011

The table and graph below give a summary of the SO_2 emissions in Scotland by broad NFR sector categories. The disaggregation of these categories is available in Appendix A (see Sector Category column).

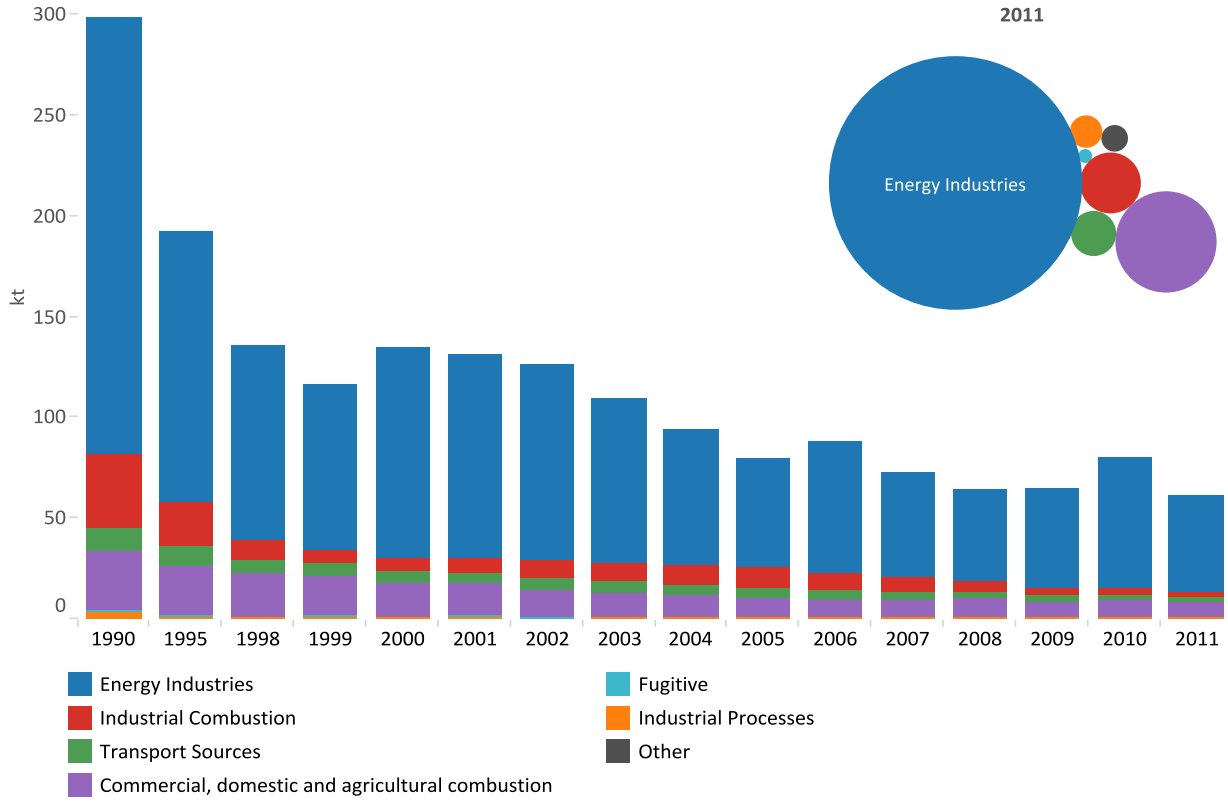
Table 2-34 Scotland Emissions of Sulphur Dioxide by Sector, 1990-2011

	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Energy Industries	216.9	135.0	96.5	81.5	104.5	101.0	96.3	82.3	67.0	53.5	64.8	51.6	46.7	49.6	65.5	47.9
Industrial Combustion	37.0	21.6	9.9	7.0	6.6	6.9	9.6	9.2	9.8	10.8	8.7	7.6	5.1	3.7	3.4	2.8
Transport Sources	11.5	9.9	7.1	6.5	5.4	4.9	5.1	4.6	4.5	4.5	4.1	3.1	2.2	2.0	1.8	1.5
Commercial, domestic and agricultural combustion	28.6	24.3	20.7	19.3	16.6	15.4	13.0	11.7	10.5	9.2	8.7	8.5	9.0	8.1	8.5	7.6
Fugitive	0.6	0.1	0.2	0.5	0.4	1.2	0.9	0.5	0.5	0.4	0.2	0.2	0.3	0.0	0.1	0.1
Industrial Processes	3.2	1.0	1.1	1.0	0.9	0.8	0.7	0.9	0.8	0.8	0.8	0.7	0.7	0.6	0.6	0.8
Other [1]	0.9	0.6	0.4	0.4	0.4	0.6	0.4	0.4	0.4	0.4	0.4	0.8	0.8	0.7	0.7	0.5
Total	**298.7**	**192.5**	**135.8**	**116.1**	**134.8**	**130.9**	**125.9**	**109.7**	**93.6**	**79.7**	**87.7**	**72.4**	**64.8**	**64.8**	**80.7**	**61.3**

Units: kilotonnes

[1] "Other" for sulphur dioxide includes emissions from Solvent Processes, Agriculture, Waste as well as 1A5b, 7A.

Figure 2-55 Scotland Sulphur Dioxide Emissions by Sector, 1990-2011

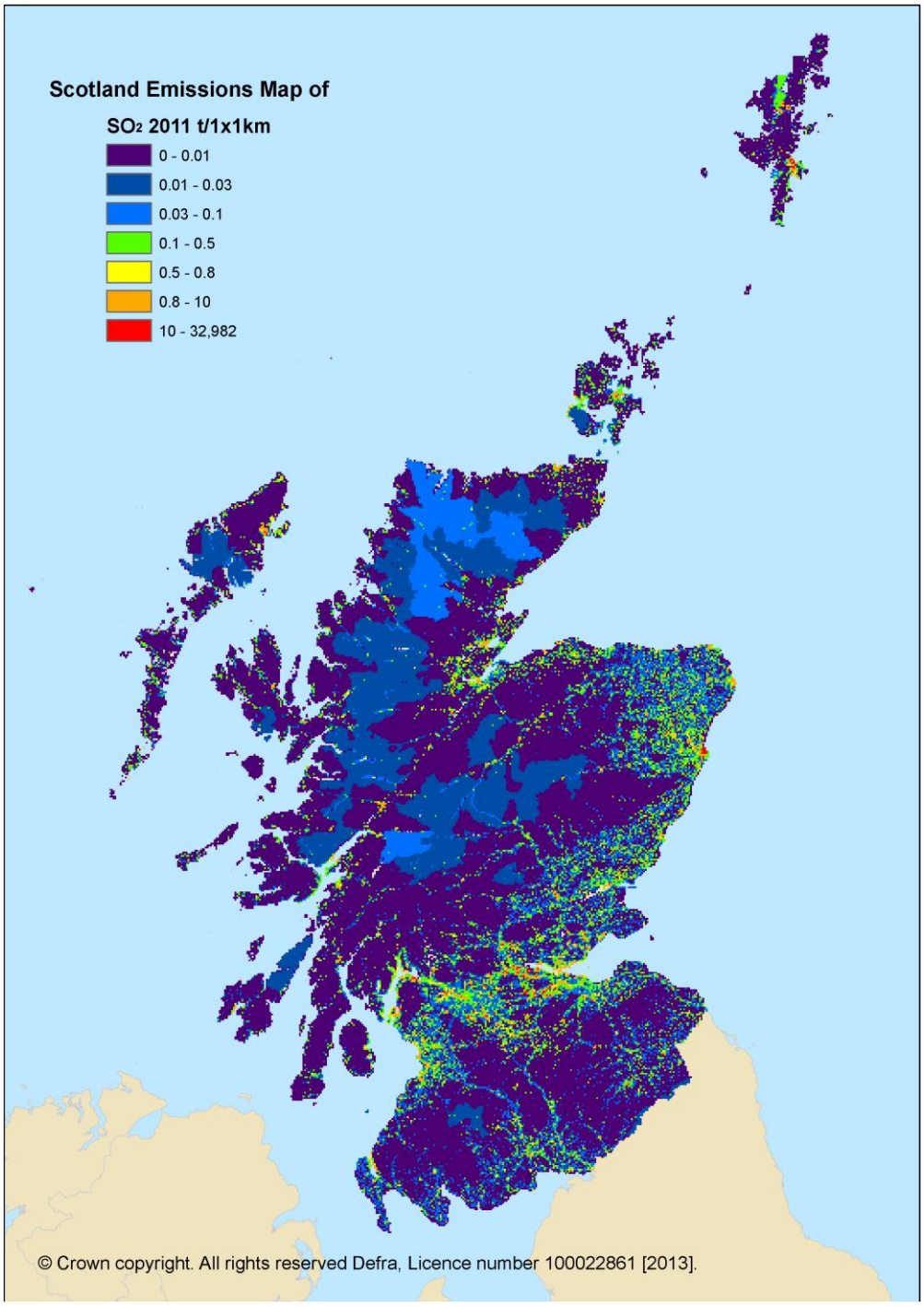


Sulphur dioxide emissions in Scotland have declined by 79% since 1990 and account for 16% of the UK total. Power generation is by far the most significant source, accounting for 68% of the Scotland total in 2011 (mainly from the sulphur in coal and fuel oil), but due to the growth in gas, renewable and nuclear fuel use, emissions from this source have reduced by 79% since 1990.

The trends in power generation fuel mix in Scotland have driven the overall sulphur dioxide inventory trend indicated in the graph above; peaks in coal-fired generation in 2006 (17,488 GWh) and 2010 (14,653 GWh) can clearly be seen in the Scotland trend (**Figure 2-49**), whilst the 2010-2011 reduction in sulphur dioxide emissions reflects the 27% reduction in coal-fired electricity generation (to 10,728 GWh in 2011). *(Note, in the table and figure above the Energy Industries sector includes power generation, petroleum refining and other energy industries such as collieries and gas processing.)*

In 2011, 5% of SO_2 emissions in Scotland are from industrial combustion (down by 93% since 1990), 10% from refineries (down 70% since 1990) whilst domestic combustion and national navigation contribute 11% and 2% of the total in 2011, respectively. The overall downward trend in SO_2 emissions across all sectors is also due to the progressive introduction of low-sulphur petroleum-based fuels such as gas oil (diesel) and burning oil.

Figure 2-56 Map of Sulphur Dioxide Emissions in Scotland, 2011



2.6.3 Wales Sulphur Dioxide Inventory by Sector, 1990-2011

The table and graph below give a summary of the SO_2 emissions in Wales by broad NFR sector categories. The disaggregation of these categories is available in Appendix A (see Sector Category column).

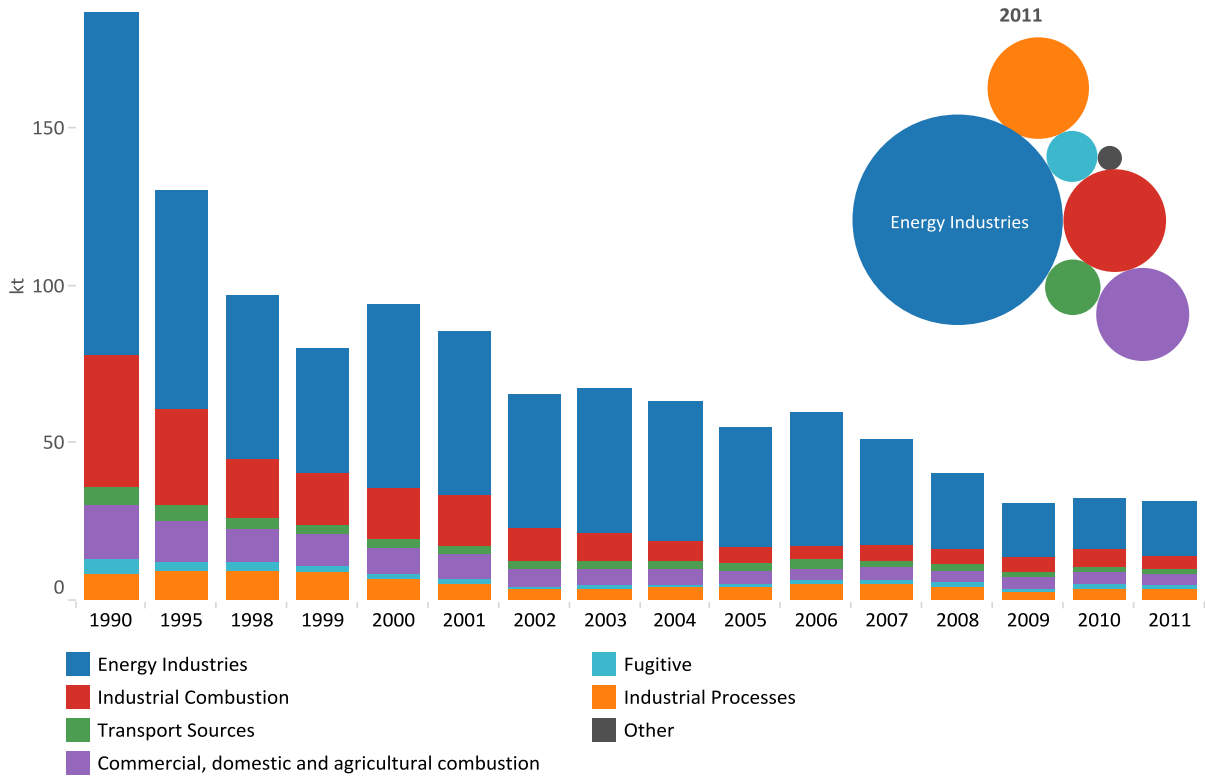
Table 2-35 Wales Emissions of Sulphur Dioxide by Sector, 1990-2011

	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Energy Industries	108.8	69.7	51.8	40.2	58.9	51.7	42.2	46.3	44.2	38.0	42.7	33.4	24.0	17.1	16.5	17.4
Industrial Combustion	41.9	30.3	19.0	16.0	16.1	16.2	10.3	8.8	6.3	4.6	4.3	5.2	5.0	4.7	5.5	4.1
Transport Sources	5.9	5.1	3.5	3.0	2.5	2.2	2.2	2.2	2.4	2.4	2.2	1.7	1.2	1.2	1.2	1.2
Commercial, domestic and agricultural combustion	17.2	13.4	10.4	9.9	8.0	7.5	5.6	5.1	4.7	3.9	3.7	3.9	4.0	3.7	3.8	3.4
Fugitive	4.1	2.0	2.3	1.9	1.4	1.6	0.6	0.7	0.8	1.1	1.0	1.1	1.3	1.0	1.5	1.0
Industrial Processes	8.7	9.6	9.6	9.1	7.4	5.7	4.1	4.2	4.4	4.6	5.7	5.5	4.4	2.6	3.7	4.0
Other [1]	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.2
Total	**186.9**	**130.3**	**96.7**	**80.3**	**94.3**	**85.2**	**65.2**	**67.5**	**63.1**	**54.7**	**59.8**	**51.1**	**40.3**	**30.7**	**32.6**	**31.4**

Units: kilotonnes

[1] "Other" for sulphur dioxide includes emissions from Solvent Processes, Agriculture, Waste as well as 1A5b, 7A.

Figure 2-57 Wales Sulphur Dioxide Emissions by Sector, 1990-2011

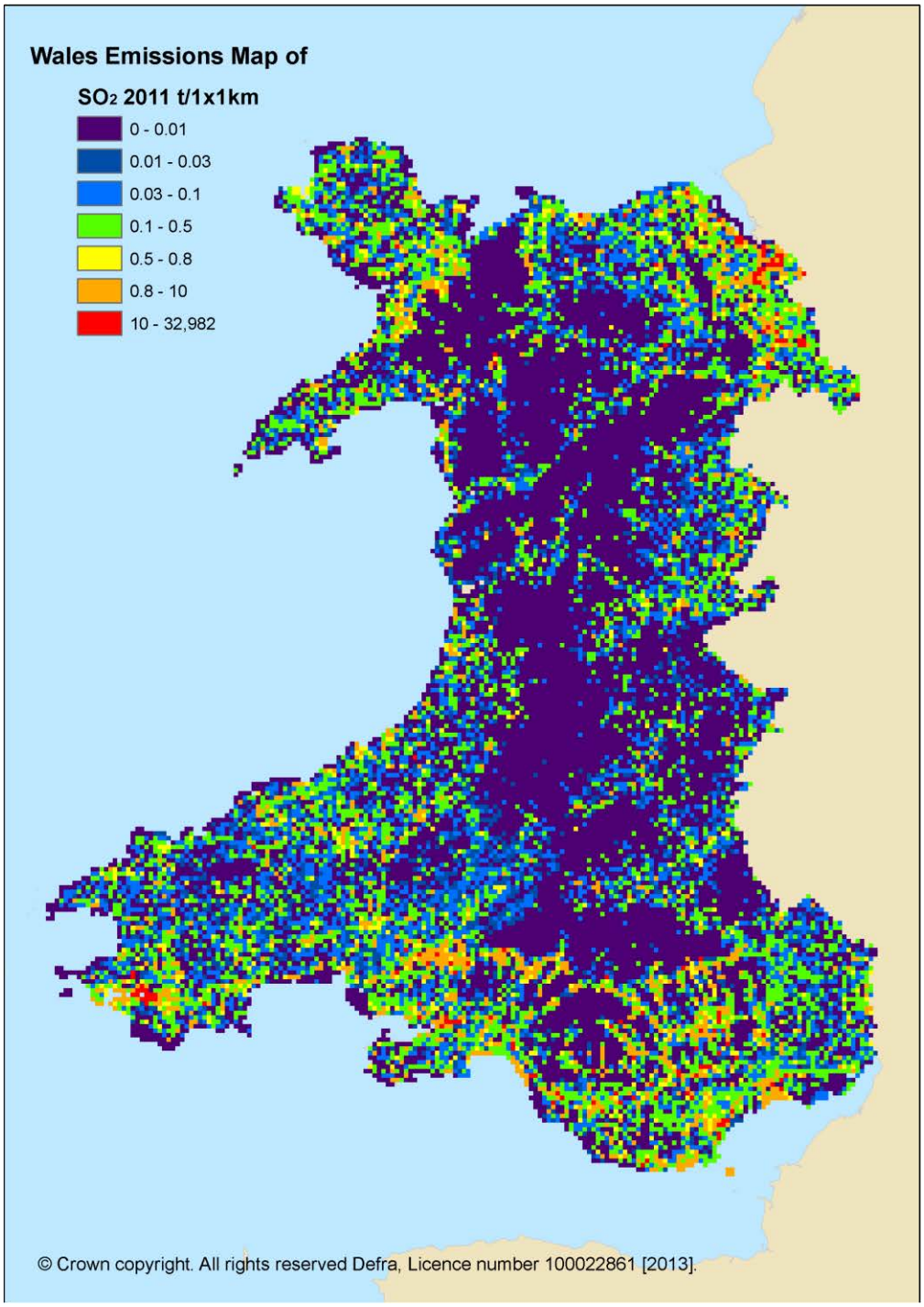


Sulphur dioxide emissions in Wales have declined by 83% since 1990 and accounted for 8% of the UK total in 2011. In 2011, emissions from petroleum refineries were the most significant source, accounting for 43% of all

SO_2 emissions (down 39% since 1990). Previously, the power generation sector was the highest emitter (43% of Wales emissions in 2007, and 53% in 2006) but the installation of Flue Gas Desulphurisation at the coal-fired Aberthaw station has led to a reduction in coal-fired generation sulphur dioxide emissions of 85% between 2007 and 2011 reducing total emissions from power generation to only 11% of the Wales total in 2011.

In 2011, 13% of SO_2 emissions in Wales are from industrial combustion (down by 90% since 1990), 10% from domestic combustion and 19% from iron and steel production (down by 42% since 1990). Reductions in SO_2 emissions across all sectors are also due to the progress towards production of low-sulphur petroleum-based fuels such as gas oil (diesel) and burning oil.

Figure 2-58 Map of Sulphur Dioxide Emissions in Wales, 2011



2.6.4 Northern Ireland Sulphur Dioxide Inventory by Sector, 1990-2011

The table and graph below give a summary of the SO_2 emissions in Northern Ireland by broad NFR sector categories. The disaggregation of these categories is available in Appendix A (see Sector Category column).

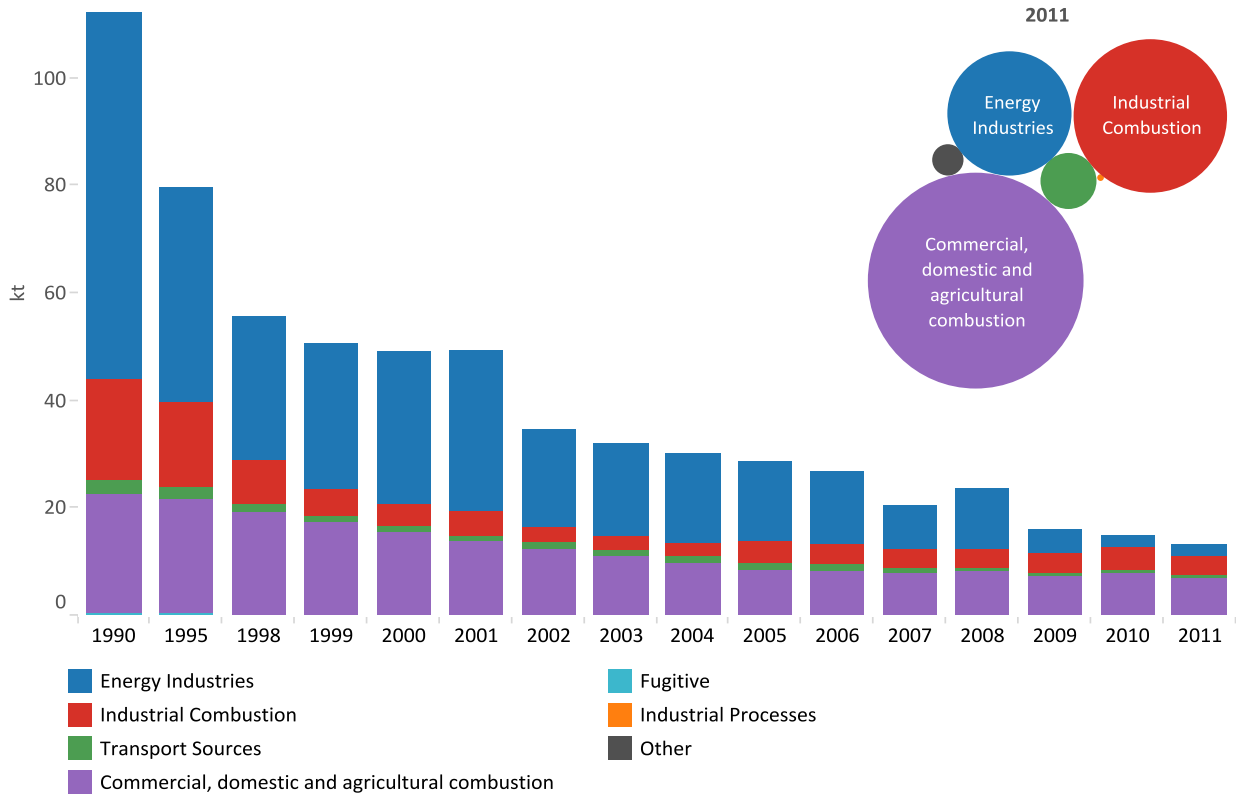
Table 2-36 Northern Ireland Emissions of Sulphur Dioxide by Sector, 1990-2011

	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Energy Industries	68.2	39.7	26.8	26.8	28.3	29.9	18.3	17.4	16.4	14.9	13.5	8.3	11.0	4.6	2.3	2.3
Industrial Combustion	18.9	15.7	8.2	5.1	4.2	4.6	2.7	2.4	2.8	3.9	3.7	3.4	3.5	3.5	4.1	3.5
Transport Sources	2.6	2.3	1.5	1.3	1.0	0.9	1.0	1.0	1.0	1.0	1.0	0.8	0.6	0.5	0.5	0.5
Commercial, domestic and agricultural combustion	22.2	21.4	18.9	17.0	15.4	13.8	12.5	11.2	9.7	8.7	8.2	7.8	8.1	7.3	7.8	6.9
Fugitive	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	0.11	0.09	0.08	0.06	0.04	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Other [1]	0.18	0.16	0.11	0.11	0.10	0.10	0.10	0.11	0.12	0.11	0.12	0.22	0.21	0.20	0.20	0.15
Total	**112.1**	**79.4**	**55.6**	**50.4**	**49.1**	**49.3**	**34.6**	**32.1**	**30.1**	**28.6**	**26.5**	**20.5**	**23.4**	**16.1**	**14.9**	**13.3**

Units: kilotonnes

[1] "Other" for sulphur dioxide includes emissions from Solvent Processes, Agriculture, Waste as well as 1A5b, 7A.

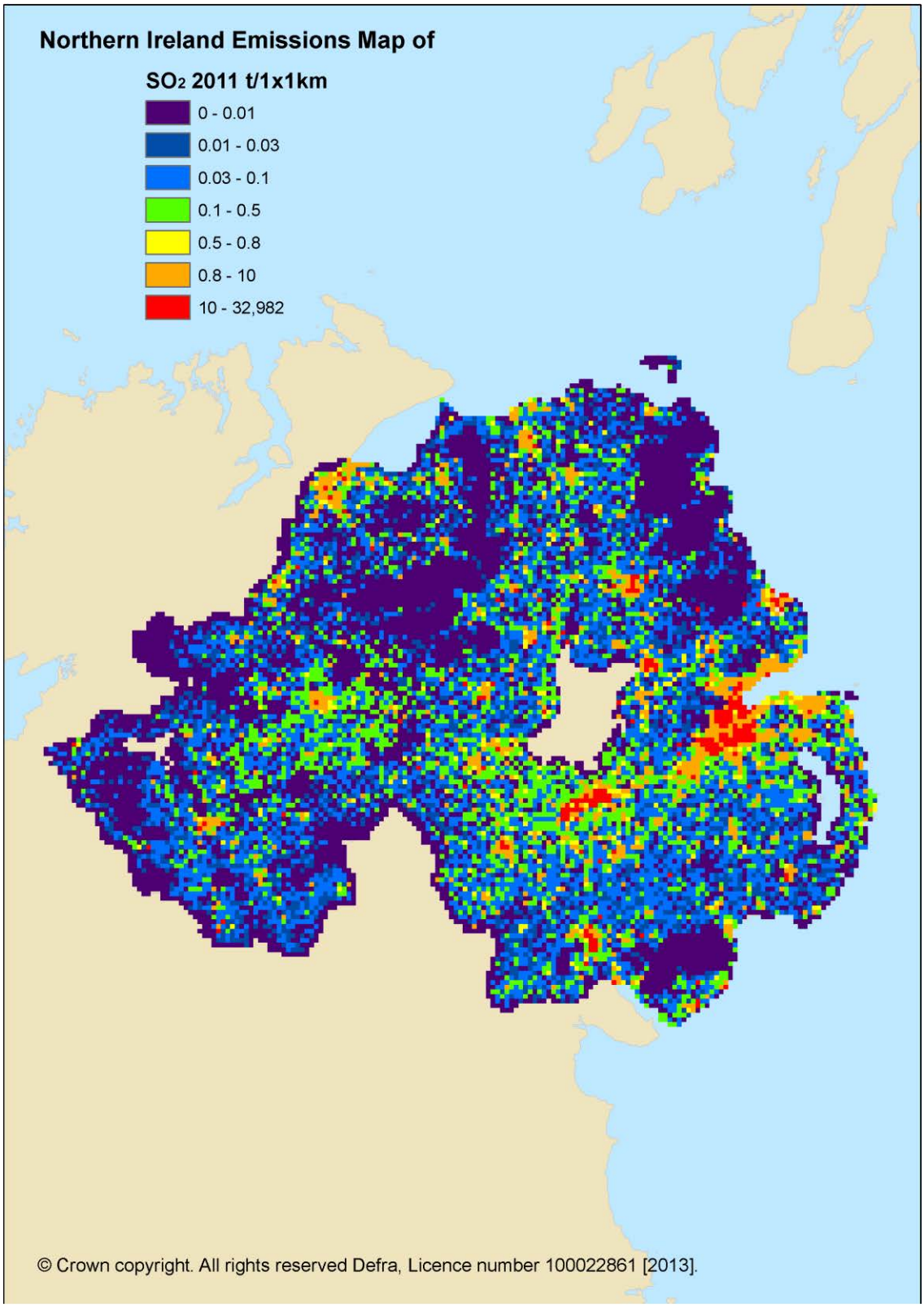
Figure 2-59 Northern Ireland Sulphur Dioxide Emissions by Sector, 1990-2011



Sulphur dioxide emissions in Northern Ireland have declined by 88% since 1990 and they accounted for 4% of the UK total in 2011. Domestic combustion is by far the most significant source accounting for 49% of the Northern Irish total in 2011 (down 59% since 1990) which is much higher than the rest of the UK, reflecting the higher use of coal and solid fuels in the domestic sector in this region. Power generation accounted for 61% of

emissions in 1990 (mainly from the sulphur in coal and fuel oil), but due to the growth in gas use, emissions from this source have reduced by 97% since 1990. 26% of SO_2 emissions in Northern Ireland are from industrial combustion (down by 81% since 1990). These emissions are expected to decline in the future as the gas supply network develops further and solid fuel use is reduced. Reductions in SO_2 emissions across all sectors are due to the use of low-sulphur petroleum-based fuels such as gas oil (diesel) and burning oil.

Figure 2-60 Map of Sulphur Dioxide Emissions in Northern Ireland, 2011

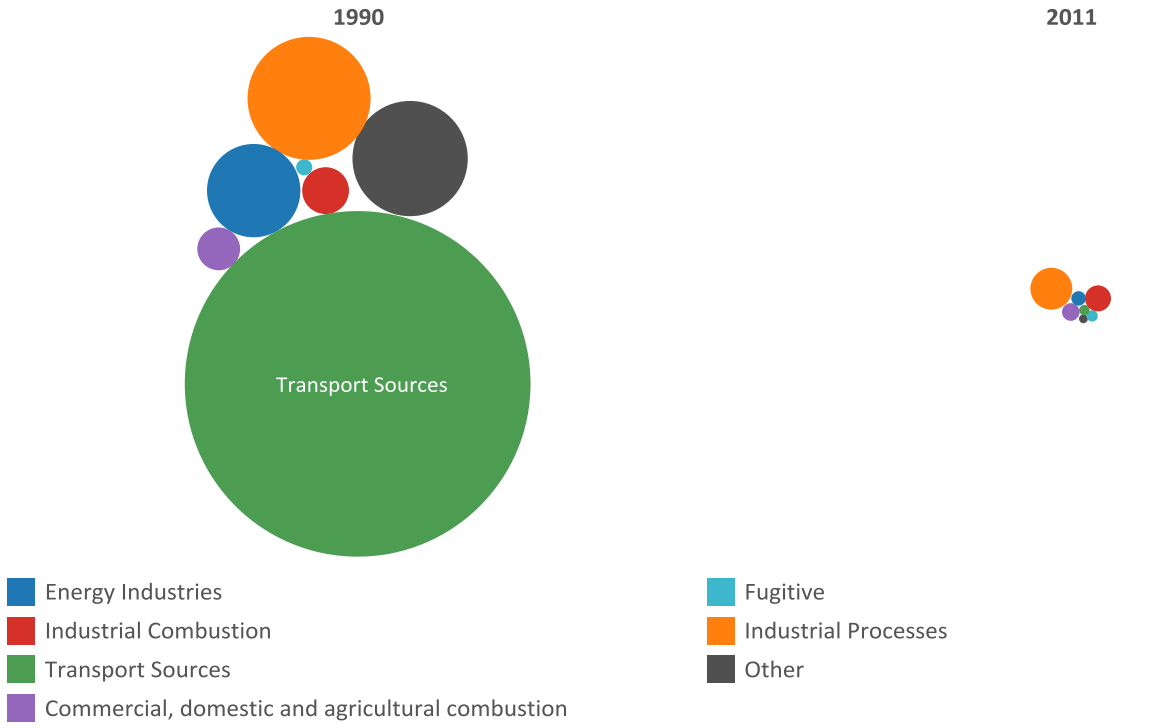


2.7 LEAD

Since 1990, emissions of lead to air in the UK have declined by 98%, with reductions in emissions occurring in most sectors. However, the decline has been mainly driven by the progressive phasing out of leaded petrol in the UK. The lead content of leaded petrol was reduced from around 0.34 g/l to 0.143 g/l in 1986. From 1987, sales of unleaded petrol increased, particularly as a result of the increased use of cars fitted with three-way catalyst and leaded petrol was then phased out from general sale at the end of 1999. The largest source of lead until 1999 was the road transport sector.

UK emission estimates for carbon monoxide are presented below for 1990 and 2011 (**Figure 2-61**). UK emissions have decreased by 76% between 1990 and 2011 as indicated by the change in area between the 1990 and 2011 graph.

Figure 2-61 UK Lead Emissions by Sector (1990 and 2011)



In 2011, transport emissions accounted for 3% of the total lead emissions. Previously this source was the most significant, accounting for 74% of emissions in 1990. In recent years, the main sources of lead emissions in the UK are from iron and steel (combustion), metal production and combustion of lubricants in industry. There has been some reduction in emissions from iron and steel production processes due to improved abatement measures. Emissions have also declined as a result of the decreasing use of coal.

- **Iron and steel sector** – this is responsible for 37% of the lead emissions in the UK in 2011, of which sinter production accounts for 74%. Emissions from sinter production have reduced by around 48% since 1990, but the proportion of annual UK lead emissions it accounts for has increased due to the decline in emissions from sectors such as transport.

- **Industrial processes** – emissions of lead from industry arise only from a few industries, dominated by metal production. Other sources include the chemical industry and solid fuel transformation. Between 1990 and 2011 emissions from metal production and the chemical industry have fallen by 95% and 96%, respectively.

- **Waste Incineration** – in 1990, lead emissions from waste incineration accounted for 8% (238t) of the overall emissions in the UK. Municipal Solid Waste (MSW) incinerators not meeting regulatory

standards were closed in the period leading up to December 1996. Improved combustion and flue gas controls, and developments in abatement technology in modern incinerator design has resulted in emissions from waste incineration declining down to less than 2% of the UK total.

Emissions of lead for England, Wales, Scotland and Northern Ireland are summarised in the tables and graphs below. **Figure 2-62** shows the split of emissions between the four Devolved Administrations for the entire time series with **Table 2-37** presenting this split as a percentage for 1990 and 2011. **Table 2-38** shows per capita emissions for 1990 and 2011.

Figure 2-62 UK Lead Emissions by Devolved Administration, 1990-2011 (tonnes)

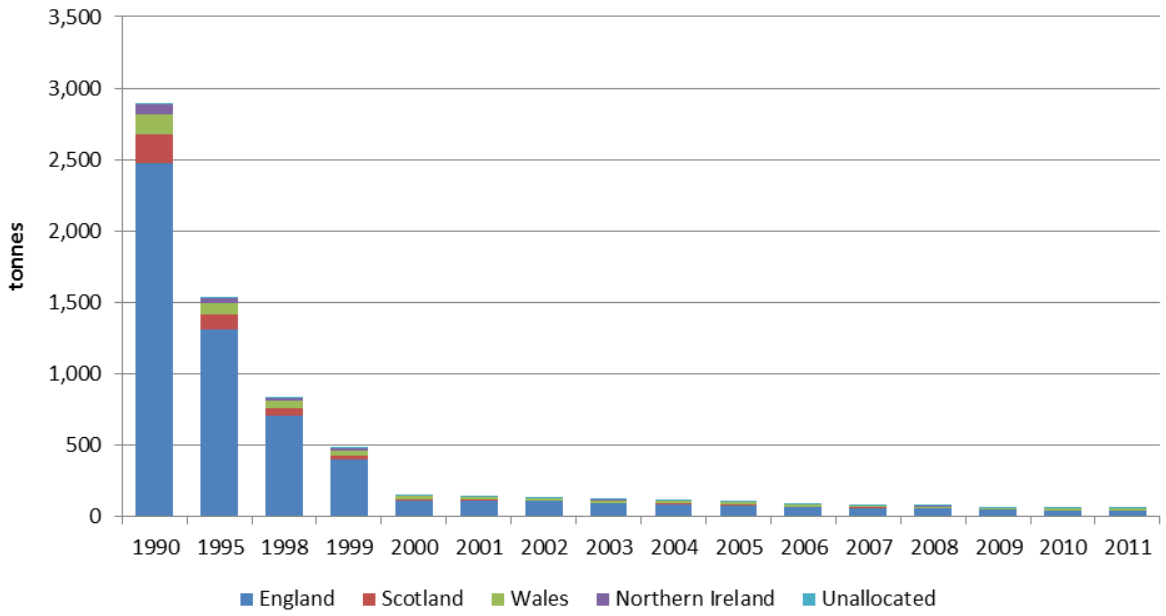


Table 2-37 Proportion of UK Lead Emissions by Devolved Administration

Year	England	Scotland	Wales	Northern Ireland	Unallocated
1990	86%	7%	5%	2%	0%
2011	71%	5%	21%	2%	0%

Table 2-38 Emissions of Lead per capita by Devolved Administration (g/head)

Year	England	Scotland	Wales	Northern Ireland	UK
1990	51.8	41.2	47.5	44.7	50.4
2011	0.8	0.6	4.1	0.8	0.9

2.7.1 England Lead Inventory by Sector, 1990-2011

The table and graph below give a summary of the lead emissions in England by broad NFR sector categories. The disaggregation of these categories is available in Appendix A (see Sector Category column).

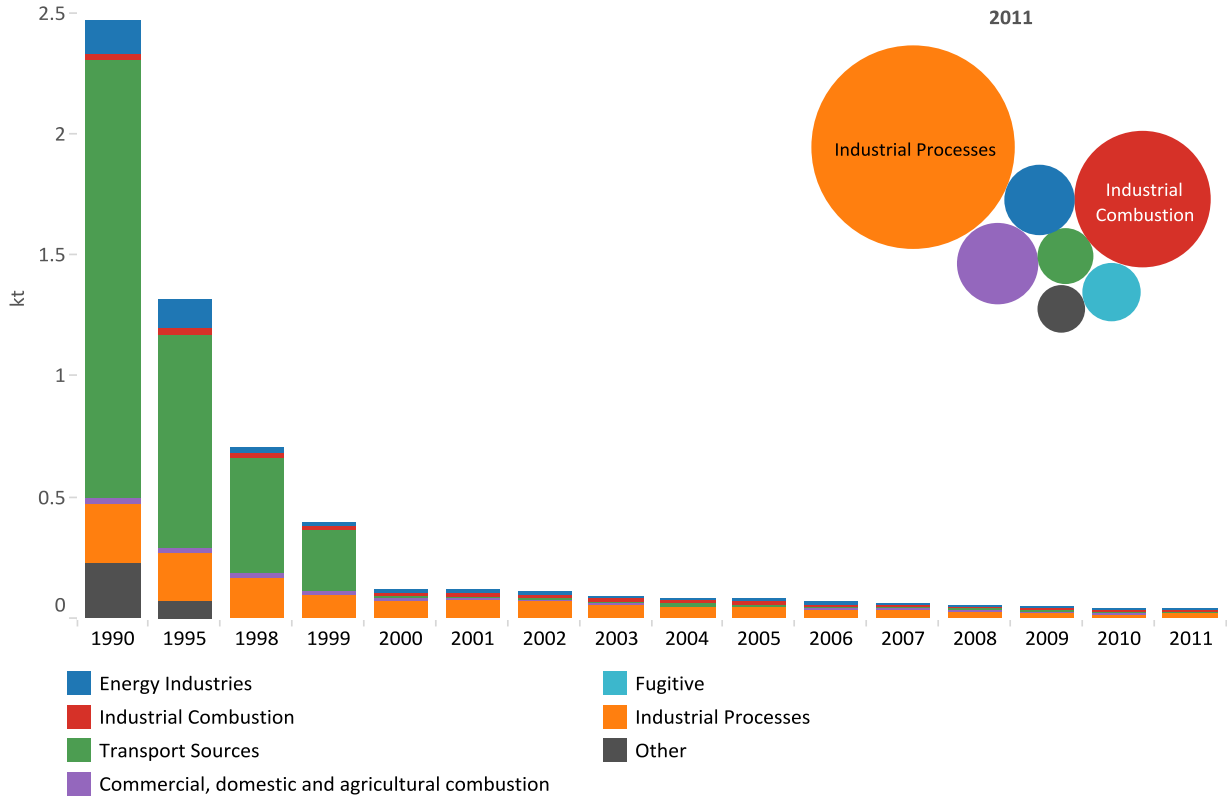
Table 2-39 England Emissions of Lead by Sector (tonnes), 1990-2011

	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Energy Industries	137.9	117.0	17.8	14.0	13.9	11.3	10.2	10.1	10.1	9.1	9.0	2.6	2.6	2.6	2.7	2.6
Industrial Combustion	31.4	25.3	19.7	16.7	13.9	14.4	14.1	13.8	14.4	12.0	9.8	10.5	9.8	12.2	10.5	9.6
Transport Sources	1800.7	878.3	481.1	253.2	2.2	2.0	2.0	2.0	2.0	2.1	2.1	1.7	1.7	1.6	1.6	1.6
Commercial, domestic and agricultural combustion	22.5	12.9	10.0	9.2	6.3	6.2	4.6	4.0	3.7	3.2	3.0	3.1	3.3	3.4	3.4	3.4
Fugitive	2.8	1.9	1.9	1.7	1.6	1.7	2.1	1.7	1.9	2.0	2.0	2.0	2.0	1.6	1.6	1.8
Industrial Processes	245.1	207.5	173.0	101.0	76.9	79.1	74.4	59.3	50.7	50.7	40.3	39.7	34.9	25.4	20.6	21.3
Other [1]	230.4	68.9	0.5	0.7	0.7	0.3	1.5	1.4	1.2	0.7	0.7	0.7	0.7	1.1	1.2	1.2
Total	**2470.8**	**1312.0**	**704.0**	**396.5**	**115.4**	**115.1**	**108.9**	**92.3**	**83.9**	**79.7**	**66.9**	**60.4**	**55.0**	**48.0**	**41.6**	**41.5**

Units: tonnes

[1] "Other" for lead includes emissions from Solvent Processes, Agriculture, Waste as well as 1A5b, 7A.

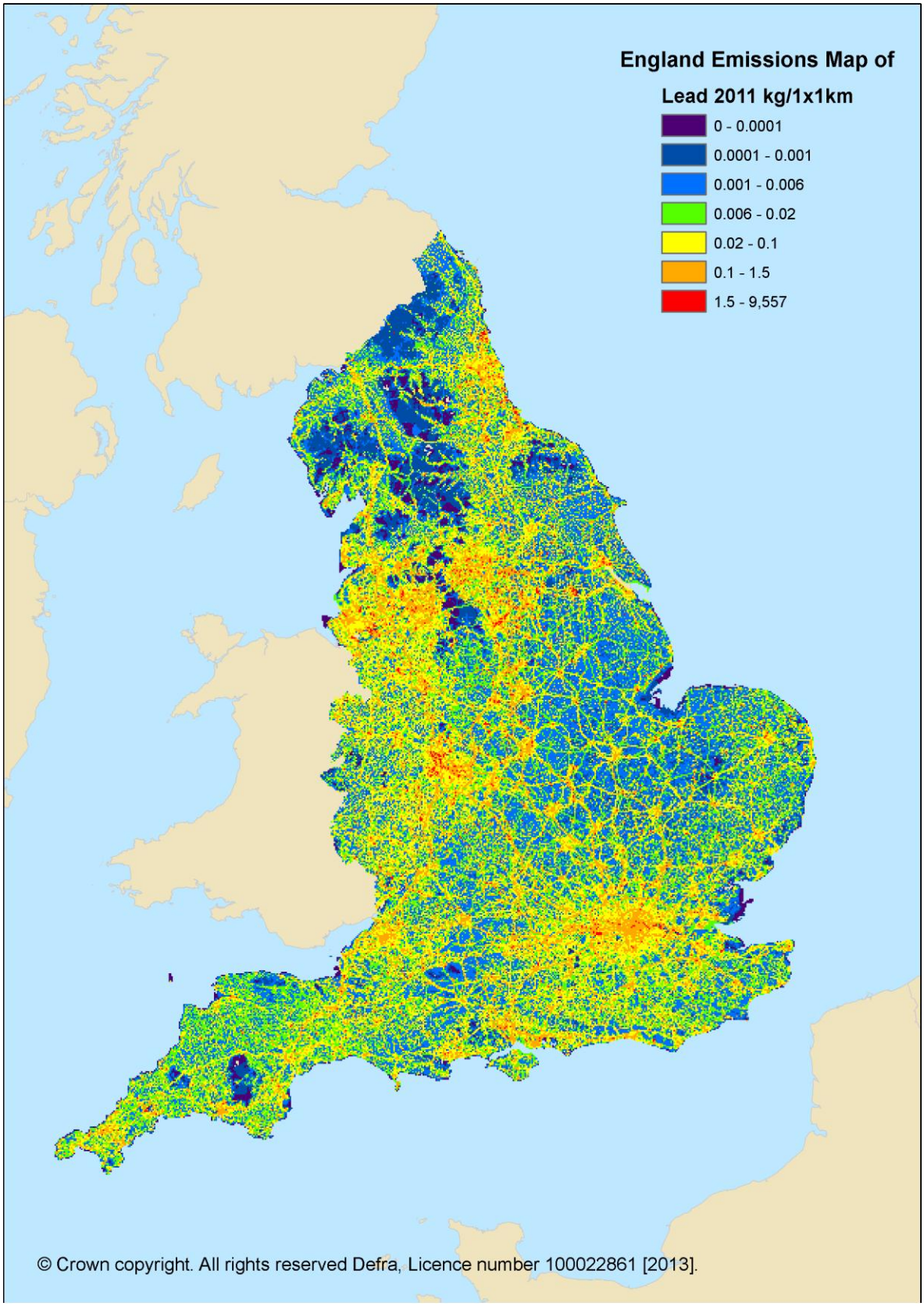
Figure 2-63 England Lead Emissions by Sector, 1990-2011 (shown in kilotonnes)



Lead emissions in England have declined by 98% since 1990 and accounted for 71% of the UK total in 2011. The emissions that arise due to production in the iron and steel industries represent the most significant source, accounting for 30% of the England total in 2011. 51% of the overall emissions are from industrial processes, including chemicals, iron and steel, aluminium and other metal production. Transport sources used

to dominate the emission of lead in England in 1990, accounting for 73%. However, as mentioned previously, due to the phase out of leaded petrol, transport sources now only account for 4% of lead emissions in England.

Figure 2-64 Map of Lead Emissions in England, 2011



2.7.2 Scotland Lead Inventory by Sector, 1990-2011

The table and graph below give a summary of the lead emissions in Scotland by broad NFR sector categories. The disaggregation of these categories is available in Appendix A (see Sector Category column).

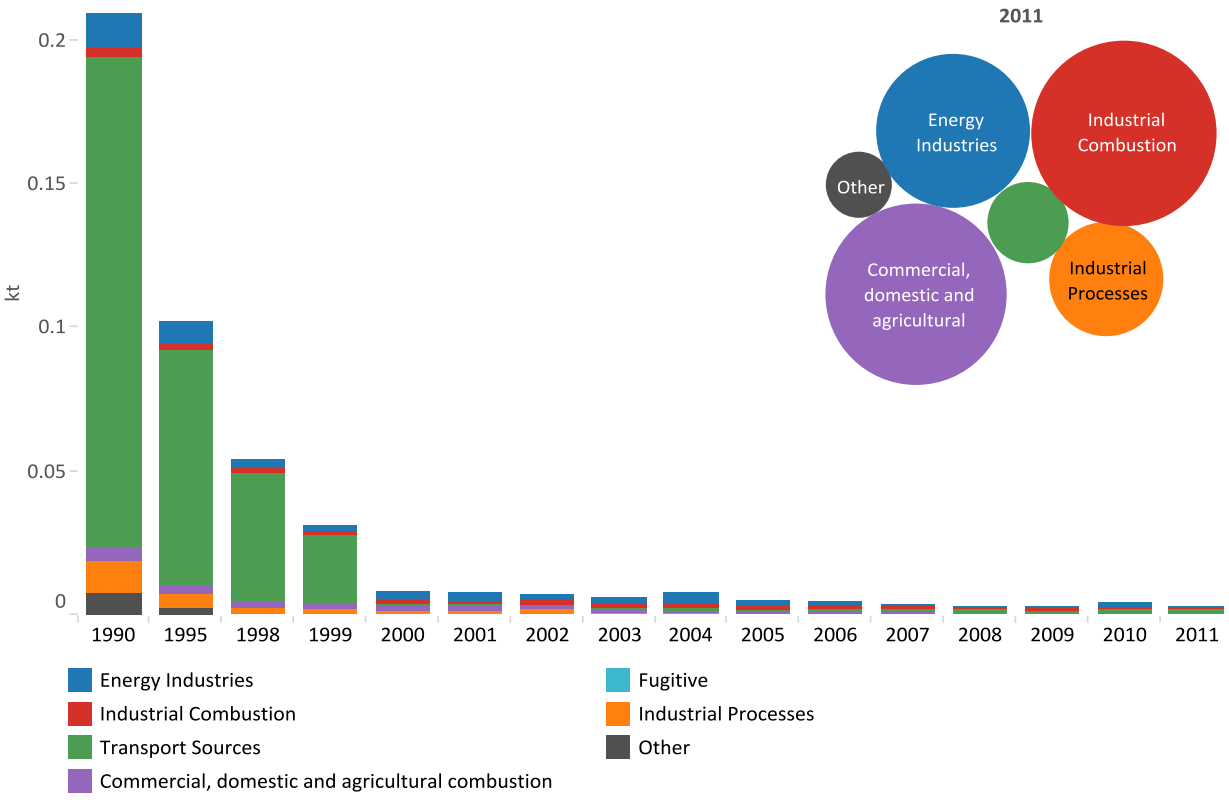
Table 2-40 Scotland Emissions of Lead by Sector (tonnes), 1990-2011

	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Energy Industries	11.8	7.6	2.7	2.2	3.0	2.8	1.9	1.5	3.3	1.6	1.7	0.8	0.4	0.7	1.3	0.6
Industrial Combustion	3.3	2.6	2.0	1.7	1.5	1.5	1.7	1.6	1.9	1.4	1.1	1.1	1.0	1.0	1.1	0.9
Transport Sources	170.7	81.6	44.2	23.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Commercial, domestic and agricultural combustion	4.4	2.4	2.0	1.9	1.5	1.4	1.2	1.0	0.9	0.7	0.8	0.8	0.9	0.9	0.9	0.9
Fugitive	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Industrial Processes	11.3	5.1	2.9	2.2	1.8	1.8	1.9	1.1	0.9	0.8	0.6	0.6	0.4	0.3	0.3	0.4
Other [1]	7.4	2.6	0.0	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	**209.3**	**101.9**	**53.7**	**31.3**	**8.1**	**7.7**	**7.1**	**5.6**	**7.4**	**4.8**	**4.5**	**3.5**	**3.0**	**3.1**	**3.9**	**3.1**

Units: tonnes

[1] "Other" for lead includes emissions from Solvent Processes, Agriculture, Waste as well as 1A5b, 7A.

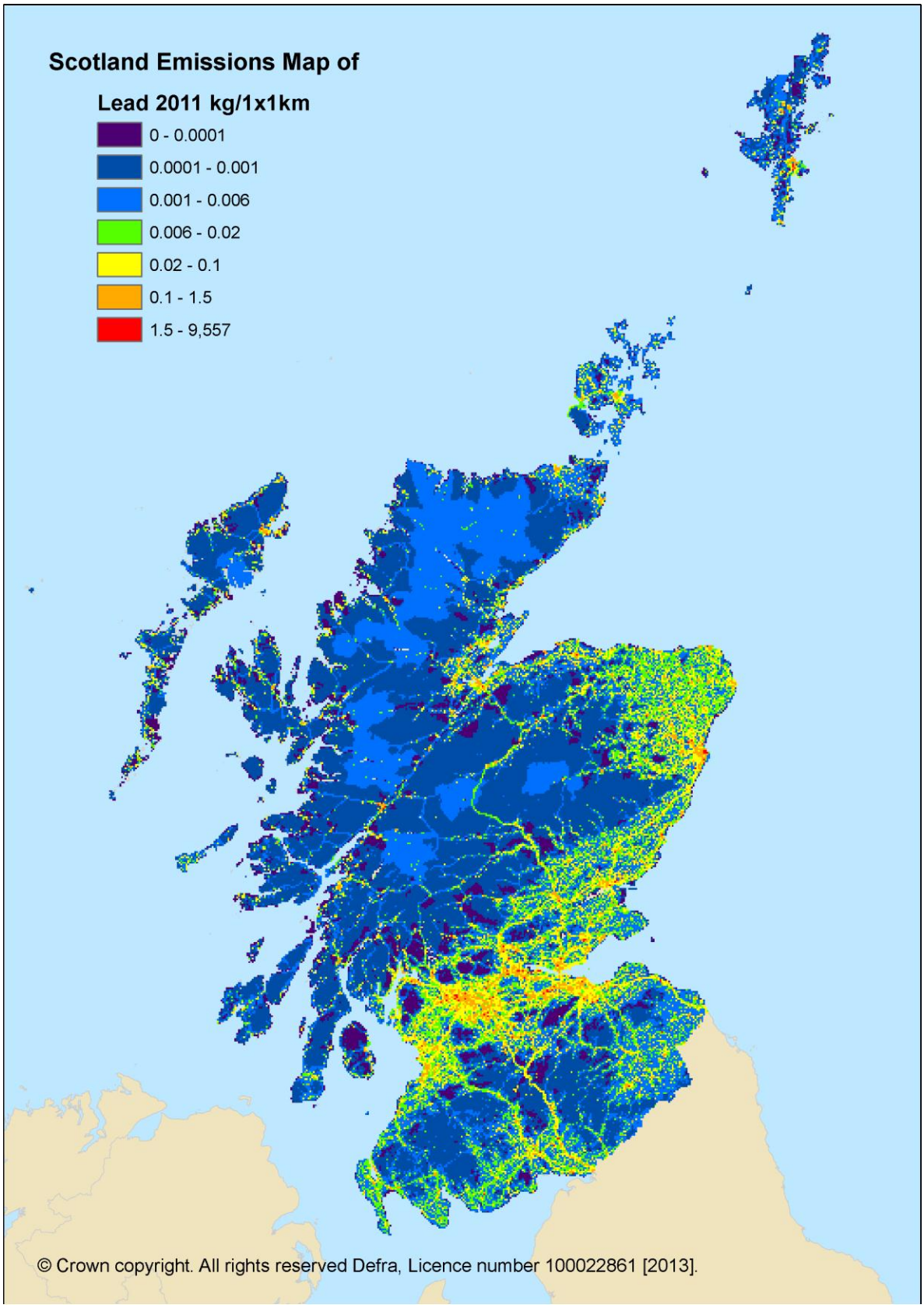
Figure 2-65 Scotland Lead Emissions by Sector, 1990-2011 (shown in kilotonnes)



Lead emissions in Scotland have declined by 99% since 1990 and accounted for 5% of the UK total in 2011. In Scotland, emissions from industrial combustion were the most significant source, accounting for 30% of the Scotland total in 2011 (down 72% since 1990). Emissions from power generation accounted for 14% but this is an increase in proportion of the overall emissions relative to 1990 when it was only responsible for 6% of

overall emissions. This is due to the decreased emissions from transport sources (down more than 99% since 1990). Emissions from domestic combustion accounted for 24% of the Scotland total emissions in 2011 (down 76% since 1990.

Figure 2-66 Map of Lead Emissions in Scotland, 2011



2.7.3 Wales Lead Inventory by Sector, 1990-2011

The table and graph below give a summary of the lead emissions in Wales by broad NFR sector categories. The disaggregation of these categories is available in Appendix A (see Sector Category column).

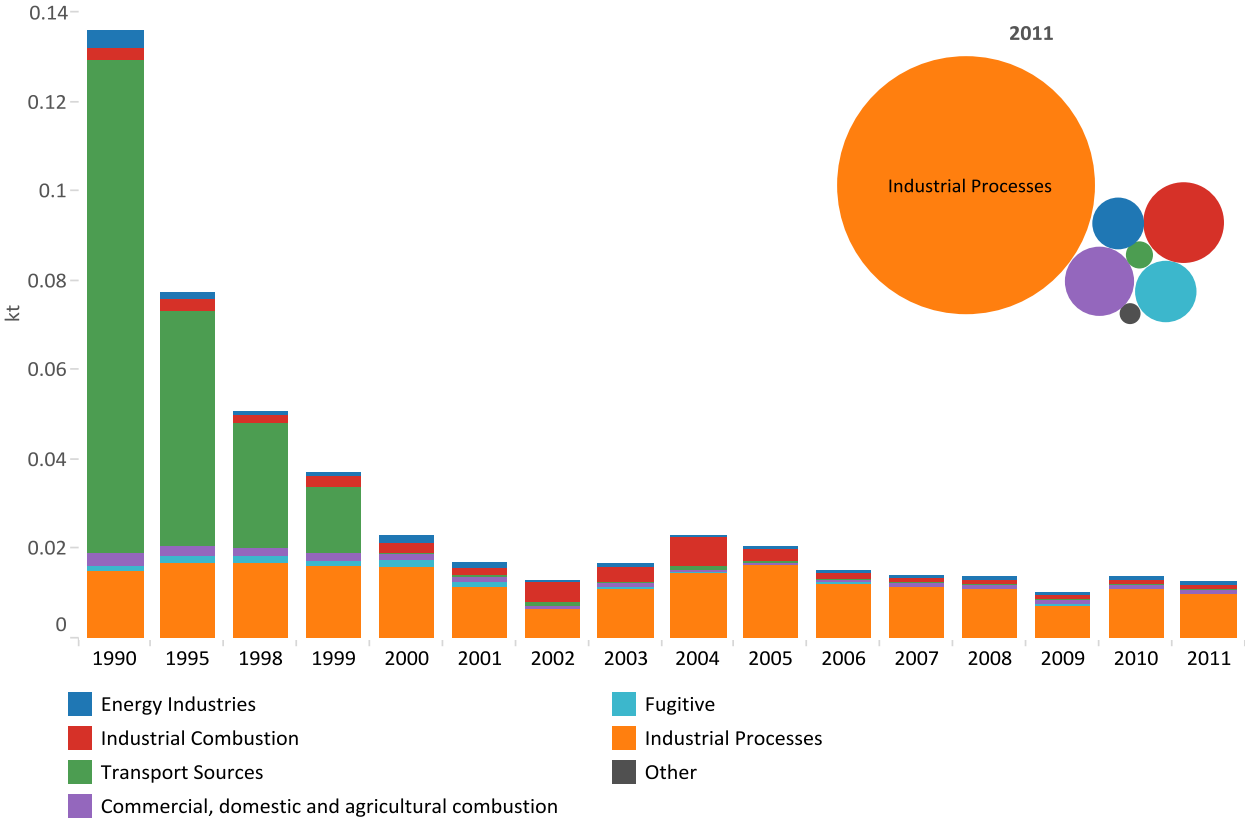
Table 2-41 Wales Emissions of Lead by Sector (tonnes), 1990-2011

	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Energy Industries	3.7	1.8	0.8	0.6	1.5	1.0	0.5	0.8	0.4	0.7	0.8	0.4	0.5	0.5	0.5	0.4
Industrial Combustion	3.0	2.4	1.9	2.5	2.4	1.8	4.7	3.3	6.7	2.7	1.0	1.0	0.9	1.0	1.1	0.9
Transport Sources	110.0	52.8	27.9	14.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Commercial, domestic and agricultural combustion	2.7	1.8	1.5	1.5	1.1	1.1	0.8	0.7	0.7	0.5	0.5	0.6	0.7	0.7	0.7	0.7
Fugitive	1.4	1.8	1.8	1.8	2.0	1.4	0.5	0.8	0.4	0.4	0.5	0.6	0.6	0.6	0.6	0.5
Industrial Processes	14.6	16.4	16.8	15.8	15.8	11.4	6.3	10.9	14.5	16.2	12.2	11.3	10.8	7.2	10.9	9.7
Other [1]	0.4	0.4	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.1
Total	**135.9**	**77.4**	**50.8**	**36.8**	**22.9**	**16.8**	**13.0**	**16.8**	**22.9**	**20.6**	**15.2**	**14.0**	**13.6**	**10.1**	**13.8**	**12.4**

Units: tonnes

[1] "Other" for lead includes emissions from Solvent Processes, Agriculture, Waste as well as 1A5b, 7A.

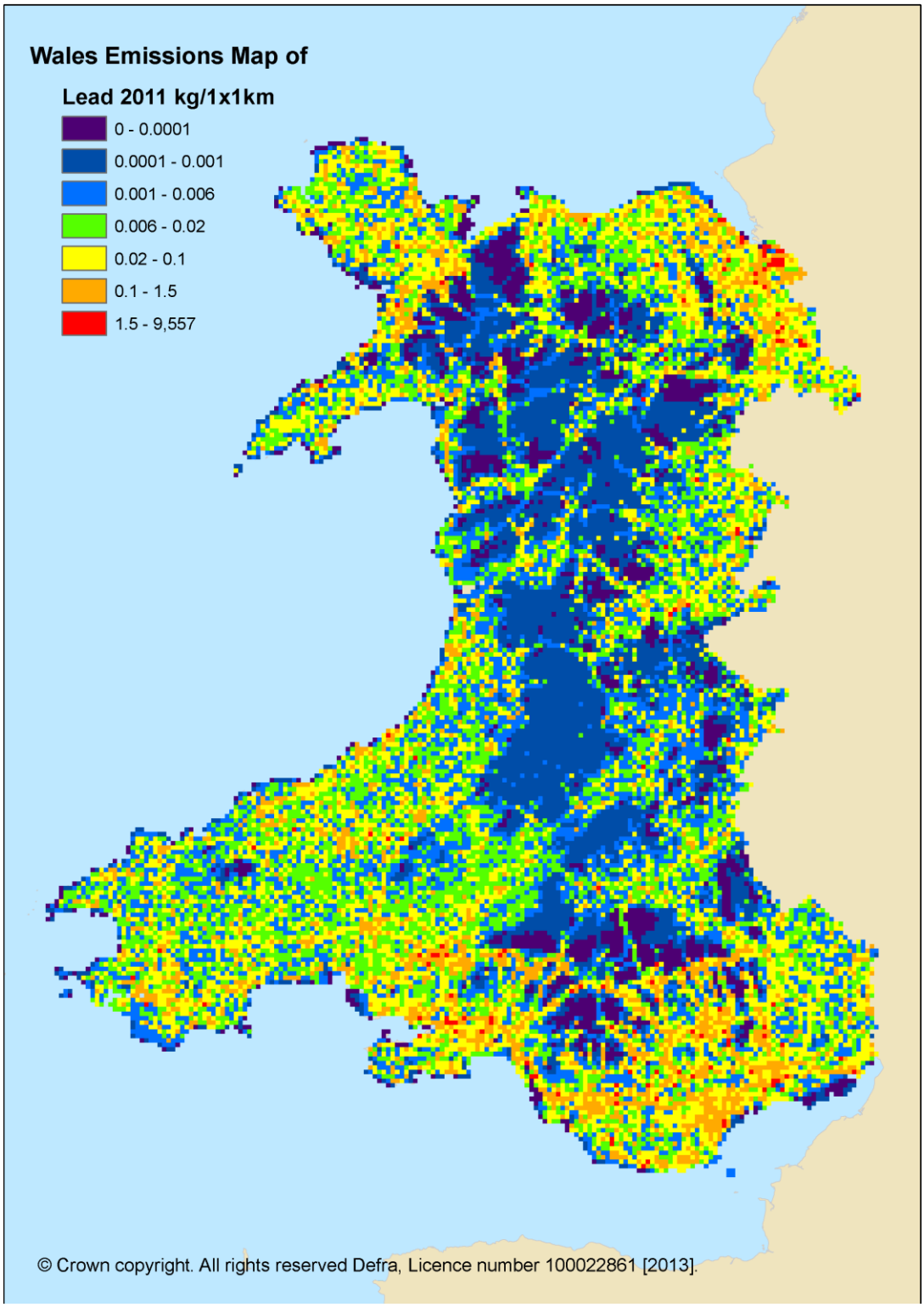
Figure 2-67 Wales Lead Emissions by Sector, 1990-2011 (shown in kilotonnes)



Lead emissions in Wales have declined by 91% since 1990 and accounted for 21% of the UK total in 2011. The emissions that arise due to the production in the iron and steel industries are by far the most significant source, accounting for 74% of the Wales total in 2011. 78% of lead emissions in Wales are from industrial

processes (down by 34% since 1990), 8% from industrial combustion and 4% fugitive emissions from fuels (down 68% and 62% since 1990, respectively), 3% arise from energy industries (down by 89% since 1990) and 1% arise transport sources (down more than 99% since 1990). The proportion of emissions from the industrial combustion sector is explained by the above average concentration of heavy industry within the country. This is the main reason that reductions in lead emissions in Wales are less than those achieved in England, Scotland, and Northern Ireland, and is also the reason per capita emissions are much higher in Wales than the other Devolved Administrations in 2011.

Figure 2-68 Map of Lead Emissions in Wales, 2011



2.7.4 Northern Ireland Lead Inventory by Sector, 1990-2011

The table and graph below give a summary of the lead emissions in Northern Ireland by broad NFR sector categories.

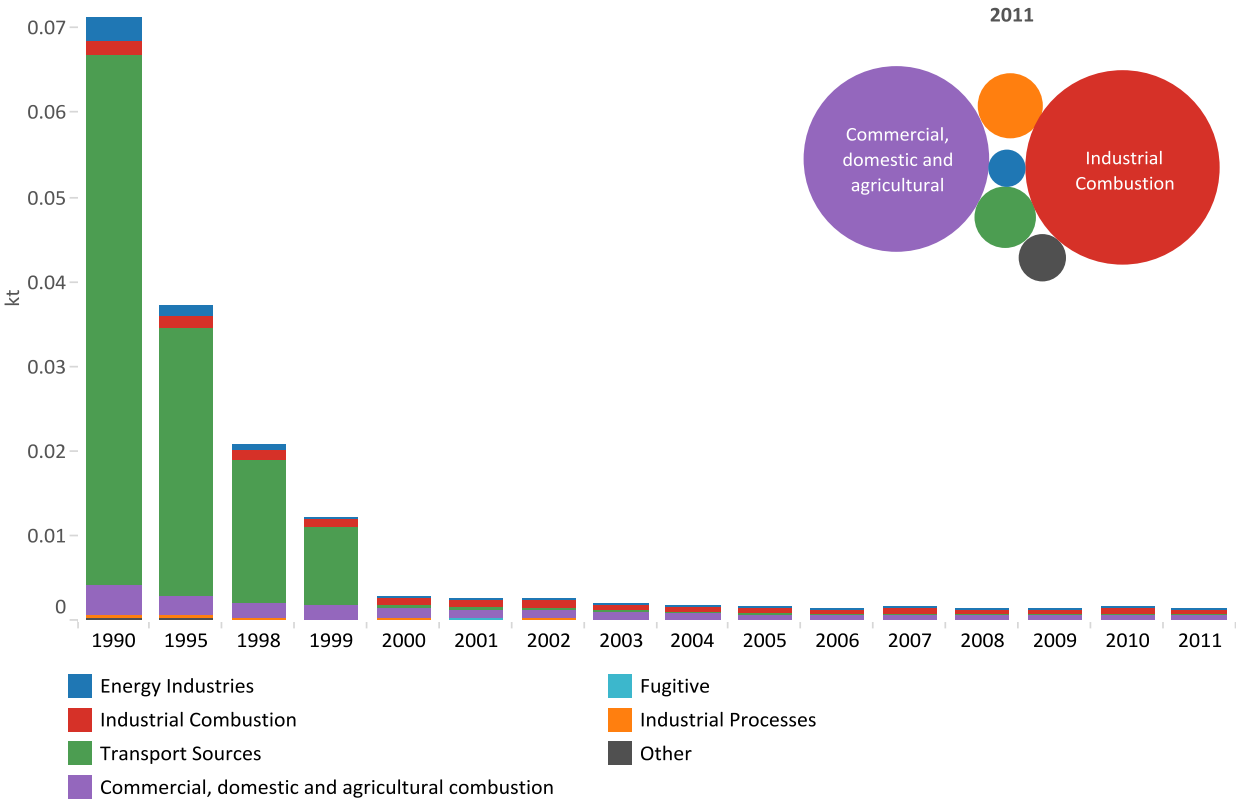
Table 2-42 Northern Ireland Emissions of Lead by Sector (tonnes), 1990-2011

	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Energy Industries	2.8	1.3	0.7	0.2	0.2	0.2	0.2	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Industrial Combustion	1.6	1.4	1.1	1.0	0.8	0.9	0.9	0.8	0.8	0.8	0.7	0.7	0.6	0.6	0.7	0.7
Transport Sources	62.8	31.7	17.0	9.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Commercial, domestic and agricultural combustion	3.3	2.1	1.7	1.5	1.3	1.1	1.1	0.9	0.7	0.6	0.6	0.6	0.6	0.6	0.7	0.6
Fugitive	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Industrial Processes	0.6	0.5	0.3	0.3	0.3	0.3	0.3	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Other [1]	0.2	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**71.3**	**37.2**	**20.8**	**12.2**	**2.8**	**2.6**	**2.5**	**2.1**	**1.8**	**1.7**	**1.5**	**1.5**	**1.4**	**1.4**	**1.6**	**1.5**

Units: tonnes

[1] "Other" for lead includes emissions from Solvent Processes, Agriculture, Waste as well as 1A5b, 7A.

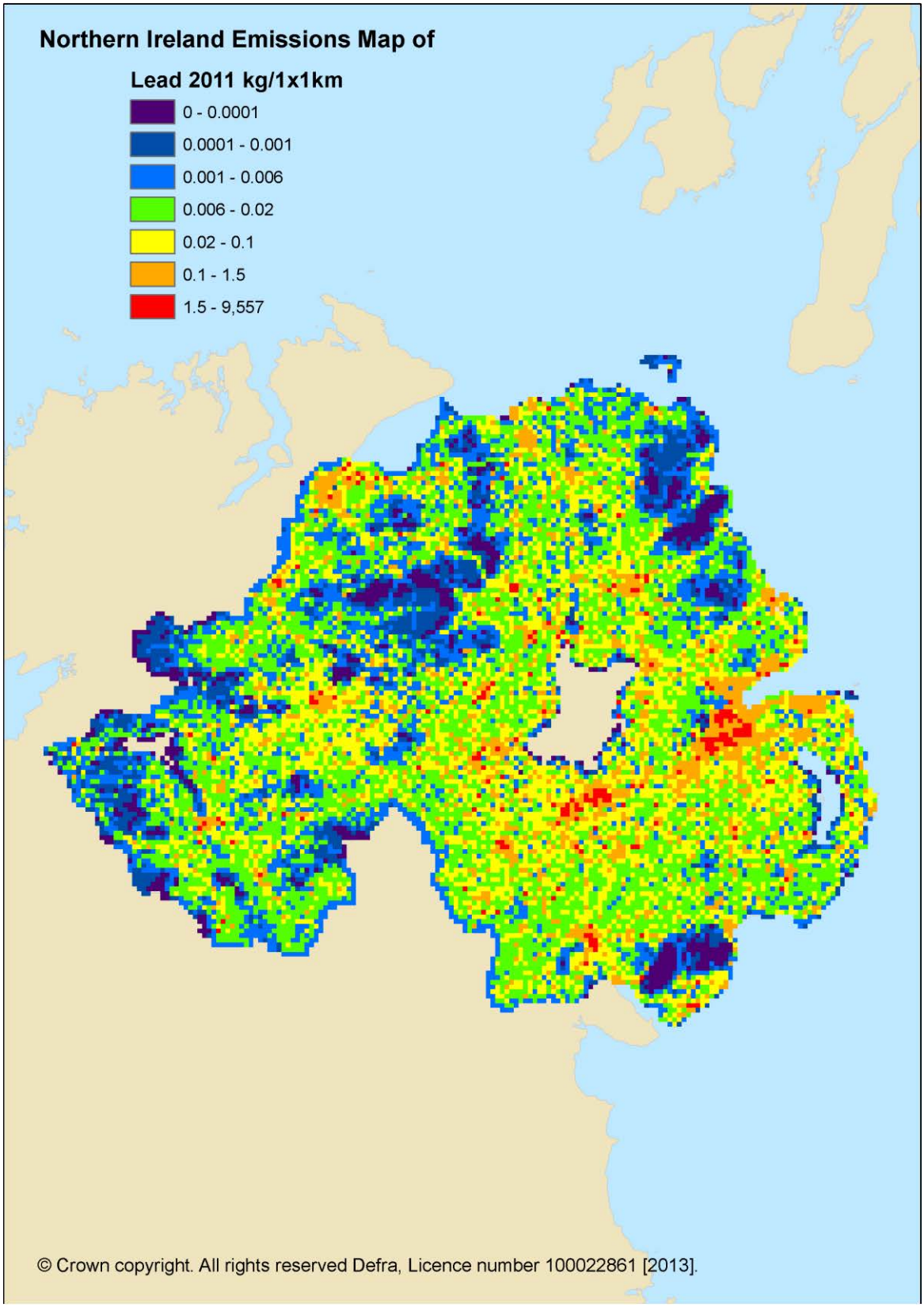
Figure 2-69 Northern Ireland Lead Emissions by Sector, 1990-2011 (shown in kilotonnes)



Lead emissions in Northern Ireland have declined by 98% since 1990 and accounted for 2% of the UK total in 2011. In Northern Ireland, emissions that arise from domestic combustion accounted for 34% of the Northern Ireland total in 2011 (down 80% since 1990). 45% of lead emissions in Northern Ireland come from industrial

combustion (down 59% since 1990), 5% from transport sources (down more than 99% since 1990) and 2% arise from power generation (down by 99% since 1990).

Figure 2-70 Map of Lead Emissions in Northern Ireland, 2011



3 Uncertainties

As discussed in Section 1.2, the air quality pollutant inventories for England, Scotland, Wales and Northern Ireland are derived using a "top-down" approach whereby the UK inventory totals are disaggregated across the four countries. For most sources there is insufficient regional data to enable a comprehensive "bottom-up" calculation to be made, and hence available proxy data are used to estimate the country-specific share of UK activity for each emission source.

The calculated uncertainties of the UK inventories for AQ pollutants are shown in the table below:

Table 3.1 Uncertainty calculated for the UK Emission Inventories of AQ Pollutants

Pollutant	Estimated Uncertainty %
PM_{10}	- 20 to + 50
Carbon Monoxide	- 20 to + 30
Oxides of Nitrogen	+/- 10
Sulphur Dioxide	+/- 4
Non-Methane Volatile Organic Compounds	+/- 10
Ammonia	+/- 20
Lead	-30 to +40

(Source: *"UK Informative Inventory Report (1980 to 2011)"*, Passant *et al*., 2013)

Further to these uncertainties in the UK datasets, there is an additional uncertainty inherent in the methodologies of disaggregating the UK emissions across the four countries. Further to this, there is greater uncertainty for emission estimates in the early years of the time series, as these estimates are frequently based on very limited historic data; in more recent years the development of environmental regulation and reporting has increased, for example through the development of annual reporting of emissions by operators of major industrial plant, regulated under Environmental Permitting Regulations (EPR) / Integrated Pollution Prevention and Control (IPPC).

The air quality pollutant inventories for England, Scotland, Wales and Northern Ireland are therefore subject to greater uncertainty than the equivalent UK estimates. The level of uncertainty is anticipated to reduce as further research is conducted and more data reporting at local and regional level is developed; one example of this is the on-going DECC sub-national energy statistics work programme, which includes annual research tasks targeted to improve local and regional energy data in specific source sectors.

The key characteristics of each inventory are discussed below, by pollutant, with an indicative "Uncertainty Rating" provided in each case.

3.1 AMMONIA

Ammonia emission estimates are more uncertain than SO_2, NO_X and NMVOC inventories due largely to the nature of the major agricultural sources. Emissions depend on animal species, age, weight, diet, housing systems, waste management and storage techniques and environmental conditions. Hence emissions are affected by a large number of factors that make the interpretation of experimental data difficult and emission estimates uncertain (DOE, 1994). Emission estimates for non-agricultural sources such as wild animals are also highly uncertain. Unlike the case of NO_X and NMVOC, a few sources dominate the inventory and there is limited potential for error compensation.

Uncertainty Rating: **HIGH**

3.2 CARBON MONOXIDE

In 2011, 34% of the UK total CO came from road transport sources (1A3b) alone, with 53% of UK carbon monoxide emissions derived from other sources of fuel combustion. Emission estimates for road transport are highly uncertain, as the available dataset of emission measurements is small and shows significant variability. Emissions from stationary combustion processes are also variable and depend on the technology employed and the specific combustion conditions. Emission estimates from small and medium-sized installations are derived from emission factors based on relatively few measurements of emissions from different types of boiler. As a result of the high uncertainty in major sources, emission estimates for CO are much more uncertain than other pollutants such as NO_X, CO_2 and SO_2 which are also emitted mainly from combustion processes. Unlike the case of NO_X and NMVOC, a few sources dominate the inventory and there is limited potential for error compensation.

Uncertainty Rating: **HIGH**

3.3 NITROGEN OXIDES

NO_X emission estimates are less accurate than SO_2 because they are calculated using measured emission factors, which can vary widely with combustion conditions; emission factors given in the literature for combustion sources show large variations. In the case of road transport (1A3b) emissions, while the inventory methodology takes into account variations in the amount of NO_X emitted as a function of speed and vehicle type, significant variations in measured emission factors have been found even when keeping these parameters constant.

From the above, one might expect the NO_X inventory to be very uncertain, however the overall uncertainty is in fact lower than any pollutant other than SO_2 for a number of reasons:

- While NO_X emission factors may be somewhat uncertain, activity data used in the NO_X inventory is very much more certain. This contrasts with inventories for pollutants such as volatile organic compounds and PM_{10}, which contain a higher degree of uncertainty in source activity estimates.

- The NO_X inventory is made up of a large number of emission sources with many of similar size and with none dominating. This leads to a large potential for error compensation, where an underestimate in emissions in one sector is very likely to be compensated by an overestimate in emissions in another sector.

- Many of the larger point-source emission sources make up the bulk of the regional estimates, and these are commonly derived from extrapolation of on-line measurement data and hence are regarded to be good quality.

Uncertainty Rating: **LOW**

3.4 NON-METHANE VOLATILE ORGANIC COMPOUNDS

The NMVOC inventory is more uncertain than SO_2 and NO_X inventories. This is due in part to the difficulty in obtaining good emission factors or emission estimates for some sectors (e.g. fugitive sources of NMVOC emissions from industrial processes, and natural sources) and partly due to the absence of good activity data for some sources. As with NO_X, there is a high potential for error compensation, and this is responsible for the relatively low level of uncertainty compared with most other pollutants in the NAEI.

Uncertainty Rating: **MODERATE**

3.5 PM_{10}

The UK emission inventory for PM_{10} has undergone considerable revision over recent years through specific research into key source sectors to improve the veracity of emission factors and improve the "bottom-up" activity data such as fuel use. Nonetheless, the uncertainties in the PM_{10} emission estimates must still be considered high, due to persisting uncertainties in some sectors regarding emission factors, activity data and particulate size distribution profiles.

Emission factors are generally based on a few measurements on an emitting source that is assumed to be representative of all similar sources. Emission estimates for PM_{10} are based whenever possible on source-specific measurements of PM_{10}, but frequently the available data is emission measurement of total particulate matter and hence conversion to PM_{10} is required based either on the size distribution of the sample collected or (more usually) on literature data on typical size distributions.

Many sources of particulate matter are diffuse or fugitive in nature, such as emissions from coke ovens, metal processing, raw material stockpiles, loading and unloading activities, construction or quarrying sites. These emissions are difficult to measure and are often dependent on conditions that vary over time and between localities such as meteorology and topography and hence are also difficult to model accurately. In many such cases it is likely that no satisfactory estimates or measurements have ever been made.

Emission estimates for combustion of fuels are generally considered more reliable than those for industrial processes, quarrying and construction. All parts of the inventory would need to be improved before the overall uncertainty could be reduced to the levels seen in the inventories for SO_2, NO_X, or NMVOC.

***Uncertainty Rating*: HIGH**

3.6 SULPHUR DIOXIDE

Sulphur dioxide emissions can be estimated with most confidence as they depend largely on the level of sulphur in fuels. Hence the DA inventories, being based upon comprehensive analysis of coals and fuel oils consumed by power stations and the agriculture, industry and domestic sectors, contain accurate emission estimates for the most important sources.

***Uncertainty Rating:* LOW**

3.7 LEAD

The lead inventory is more uncertain than SO_2 and NO_X inventories, and the certainty of the emissions varies over the time-series as different source sectors dominate at different times due to the very significant reductions in emissions from the key sources in 1990, notably road transport. From the key sources in 1990, the lead emission estimates were based on measured concentrations of lead in the fuels, which were tightly regulated prior to being phased out in the late 1990s. This gives a high confidence in the estimates for those sources of fuel combustion, which dominated in the early 1990s, but are now much reduced.

In more recent years, the level of emissions is estimated to be very much lower, and derived from a smaller number of sources. The metal processing industries are mainly regulated under IPPC and the estimates provided by plant operators to the regulatory agencies and used in the national inventories are based on emission measurements or emission factors that have been researched for the specific process type. There is a moderate level of uncertainty associated with these annual emission estimates due to the discrete nature of the stack emissions monitoring techniques and determination of mass emission flow rates from point sources. Furthermore the variability of lead content of raw materials such as fuels (e.g. coal) is such that the discrete lead emission measurements provide a snap-shot of the process and plant performance, and there is some

uncertainty as regards how representative that result may be for use in scaling up to provide annual emission estimates. These uncertainties are inherent within the inventories from environmental regulators of EPR/IPPC industries and are unavoidable; the emissions data from IPPC regulated installations used in the compilation of these DA inventories are subject to a managed process of quality checking by the environmental regulatory agencies and are regarded as the best data available for inventory compilation.

The observed year-to-year variations in emission estimates are based on actual trends reported by plant operators and may reflect changes in lead content of raw materials. The uncertainty in emission monitoring applies to all pollutants to some degree, but more so for pollutants such as lead for which (i) no continuous emission monitoring systems are available, and (ii) where fuel composition is known to be highly variable depending on the fuel source. This is not the case for species such as NO_X and SO_2 where many regulated sites will use Continuous Emission Monitoring Systems and the fuel elemental composition is either not a significant factor in process emissions or does not vary as much as for heavy metals and other trace contaminants. The emission estimates of lead from other smaller-scale combustion and process sources from industrial and commercial activities are less well documented and the estimates are based on emission factors that are less certain than those based on regulatory emissions monitoring and reporting.

Uncertainty Rating: **MODERATE**

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